International Committee on Oxisols: Final Report

S. W. Buol
and
Hari Eswaran

Joint contribution of

Soil Management
Support Services

Tropical Soils
Research Program
North Carolina
State University

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Preface

In 1978, to address the growing awareness of the problems in classifying Oxisols and Oxisol-like soils, a group of interested soil scientists from around the world was formalized into ICOMOX, the International Committee on Oxisols. Since there was no headquarters, the committee operated as a network of correspondents, with many members known to each other by name only and not personally.

From 1978 through 1986, these scientists shared their data, concerns, and suggestions and presented final recommendations for amendments to the Oxisols classification in Soil Taxonomy. In 1987, USDA/SCS published the Oxisols amendment, Part 615.45, in the National Soil Taxonomy Handbook. Thus, the ICOMOX committee is now dissolved, although the friendships and respect such mutual sharing generated continues.

Circular letters as a means of sharing data and building consensus began with Frank Moorman, head of ICOMLAC, The International Committee on Low Activity Clays. The chair wrote a letter, circulated it, obtained and compiled responses to his proposals, then presented a revised proposal in the next Circular Letter. In addition, the chair often corresponded directly with each person who contributed suggestions or comments, or met with them personally.

The letters presented in this volume are abstracts of the responses received and reprints of parts of the revised proposals. The original letters contain comments, data, and other attachments from the various committee members, as well. These data and responses were or were not incorporated into the Oxisols criteria. As stated in Circular Letter No. 9:

> Most of the letters pointed out sections . . . that were not clear. These comments are extremely valuable in our attempt to produce an easily understood document. Some of the letters raised basic questions about class limits, and, as you may expect, all points of view are not the same; in fact, some are quite contrasting.
>
> In [these] circular letter[s], I will attempt to summarize the opposing points of view and thereby solicit comments from each of you. The greater the resource base, the better chance we have to arrive at rational groupings of Oxisols. Guy [Smith] often used the phrase "rational" grouping rather than "correct" or "proper" grouping. According to my dictionary, rational has as one definition "agreeable to reason." Hopefully, our rational groupings can also be agreeable to most soil scientists.

We are grateful to all the rational men and women who served on this committee and who were dedicated to improving Soil Taxonomy.

Contents

Introduction

Soil Taxonomy (Soil Survey Staff 1975, p. 323) recognized that "The classification of Oxisols has lagged behind that of the other orders of mineral soils." Most of the data used were from Oxisols in Hawaii and Puerto Rico, and the system needed to be tested more widely.

Moreover, final publication of Soil Taxonomy upset many users of the 7th Approximation (Soil Survey Staff 1960) because it gave clear precedence to the presence of an argillic horizon over the presence of low-activity clay, which long had been considered a dominant feature of "highly weathered tropical soils." In keying out soils in the 7th Approximation, the Oxisols were defined before the Alfisols and Ultisols by the statement: "Other mineral soils having an oxic horizon or having, within 30 cm of the surface, plinthite that forms a continuous phase and that has not hardened." In Soil Taxonomy, 15 years later, however, the key definition for Oxisols stated: "Other soils that: (1) Have an aquic moisture regime and have plinthite that forms a continuous phase within 30 cm of the surface of the mineral soil; or (2) Have an oxic horizon within 2 m of the soil surface but do not have a plaggen epipedon and *do not have* either an argillic or a natric horizon that overlies the oxic horizon [italics ours]."

Vast areas and many well-studied kinds of soils were affected by this change. The critical question at many of these pedons was the ability of soil scientists to consistently identify the presence of an argillic horizon when the horizon in question had exactly the same chemical exchange properties and mineral composition as those defined by an oxic horizon. The one feature that could be attributed to the argillic horizon and not to the oxic horizon was the presence of clay skins, which were assumed to be morphological features proving a genesis by illuviation of layer-lattice silicate clays. The continuum of clay skins from "true" oxic horizons to "true" argillic horizons was recognized in the discussion of oxic horizon characteristics: "Clay skins may be present only at a depth greater than 1 m if roots are scarce; but if they occupy more than 1 percent of the volume of any subhorizons, they indicate the presence of an argillic horizon" (Soil Survey Staff 1975, p. 38). Thus for many pedons placement at the order level of Soil Taxonomy rested on a quantity of 1 percent of volume of clay skins. Analysis by thin sections seemed the only acceptable method for careful study, but to obtain significant confidence of a 1 percent volume, upward of 150,000 points should be counted (Brewer 1976). Needless to say, thin-section anaylsis is extremely limiting as a criterion for classification of a soil.

To address the growing awareness of the problems in classifying Oxisols and Oxisol-like soils, a group of interested soil scientists from around the world was formalized in 1978 into the International Committee on Oxisols (ICOMOX) with Hari Eswaran, then with the Geological Institute in Ghent, Belgium, as chairman. Many of the members of the Committee (see List of Contributors) were also members of the International Committee on Low Activity Clays (ICOMLAC) chaired by Frank Moormann. After authoring seven circular letters, Eswaran became head of the Soil Management Support Services (SMSS) and thus responsible for all international committees working to improve Soil Taxonomy. He turned the chairmanship of ICOMOX over to S. W. Buol in 1981.

During the 8 years that ICOMOX functioned as an international committee, 17 circular letters and three international workshops served as its most obvious activity. However, there were countless numbers of individual correspondence that provided the exchange of data and concepts so necessary to a better understanding of the soils we now classify as Oxisols.

The following items summarize some of the changes this group proposed to the Soil Survey Staff concerning not only the classification of Oxisols but also relating to the general structure of Soil Taxonomy. The Committee proposed:

1. Subgroup keys directing the users' attention to properties of the pedon being classified rather than to an idealized concept of a great group.
2. Use of the perudic soil moisture regime as a suborder criterion in Oxisols.

3. An allic reaction class based on exchangeable Al^{+++} content in Oxisols.
4. Use of kaolinitic or halloysitic in families with less than 35 percent clay in Oxisols.

Within the classification structure of Oxisols, many changes were proposed. The order of Oxisols still has to be considered less well tested than many of the other orders because we lack the experience of establishing many series in the sixth category of the system. No doubt the opportunity to travel and examine carefully characterized Oxisol pedons on three continents, with data from a fourth, has benefited the participants. Observations of the users of Oxisols under different economic and agricultural systems has served to cause all of us to better evaluate their potential.

This volume was prepared, as was Excerpts from the Circular Letters of ICOMLAC (Moorman 1985) to give wider circulation to the deliberations and concerns of soil scientists as they attempted to bring about improvements in Soil Taxonomy and its forerunner, the 7th Approximation, headed by Guy Smith and his staff. This volume is intended to provide future soil scientists with a candid record of concerns and limitations of soil science during this period of development. We all recognize that the results of this work are but a stepping stone to future improvements in Soil Taxonomy because, as was so well stated by Kubiena (1948), "Perfect scientific classification is first possible when one knows everything concerning the classified natural objects." Despite the efforts of so many on the Committee, and others, to assemble and exchange the available data, there are none who would proclaim they know everything concerning Oxisols.

The Circular Letters

Circular Letter No. 1, January 1978

In the initial circular letter, "acting chairman" Hari Eswaran (ICOMOX was not officially formed at this time) put forth the following initial proposals for classification of Oxisols. Fred Beinroth had requested the formation of a committee to examine the classification of Oxisols, and Jack McCelland (USDA-SCS) had reacted favorably to the idea. Jakob Bennema and Juan Comerma had submitted proposals regarding the proposed Oxisol classification to Frank Moorman (ICOMLAC), which Eswaran considered in this letter.

Classification of Oxisols—Initial Proposals

The discussions in Brazil by members of ICOMLAC clearly indicate diverging opinions on the limit between the Alfisols and Ultisols with low-activity clays (LAC) and the Oxisols. There are some who would like to narrow the concept of Oxisols and others who would do the reverse. A third minority would like to break away from the present concept in Soil Taxonomy and group all soils with low-activity clay — irrespective of the presence of an argillic horizon — into a separate order of soils. In some instances, I had the feeling that proposals were being made as compromises with flimsy justifications.

It is true that LAC soils with an argillic horizon have some properties similar to Oxisols. The argillic horizon differentiates these soils from Oxisols, and it is important that we retain this distinction. The argillic horizon is falling into disfavor with some people due to difficulties in its identification, especially in areas where Alfisols and Ultisols occur in association with Oxisols. I consider this a temporary problem, as micromorphological techniques will be used to a greater extent in the future and soil micromorphology is the only technique available for identifying translocated clay.

Consequently, the question is how to set limits to the argillic and oxic horizons. Because Oxisols are keyed out earlier than the Ultisols or other soils with argillic horizons, it is necessary to define the Oxisols more precisely. More specifically, the definition should spell out the limit between the Oxisols and LAC soils and later make provisions for possible intergrades.

The same changes are also needed in the definition of the oxic horizon. These are minor, however, and do not drastically change the concept.

The proposals given below for changes in the suborders and great groups are based mainly on my Malaysian experience. Some of the changes proposed stem from difficulties in using the present parameter. An example is the Tropeptic subgroup.

The modified classification is presented below for your criticisms and comments. The classification is only developed up to the great group level. The Acrox is proposed as a new suborder. Only the definitions for the great groups in the Acrox and Orthox are given as illustrations of my thinking.

Some of the changes I propose are radical and I anticipate violent responses.

Summary of Properties of the Oxic Horizon (modified from Soil Taxonomy page 39)

The oxic horizon is a subsurface horizon, exclusive of the argillic or natric, that:

(1) Is at least 50 cm thick.
(2) Has an effective CEC (meq bases extractable with NH_4OAc plus aluminum extractable with 1*N* KCl) of 12 meq or less per 100 g clay.
(3) Has a CEC by NH_4OAc at pH 7 of 16 meq or less per 100 g clay.
(4) Has pH in 1*N* NaF (ratio 1:50) of less than 9.5.
(5) Does not have more than traces of primary weatherable minerals in the sand fraction. The silt may have small amounts of muscovite in addition to kaolinite, quartz, and other resistant minerals such as ilmenite and magnetite. X-ray diffractograms of clay may have weak peaks of 10Å and 5Å for muscovite and in addition a peak at 14Å, which does not collapse on heating or expand on glycerol solvation, indicating Al-chlorite. The clay fraction has no feldspars, other micas, or ferro-magnesian minerals.
(6) Has textures of loamy fine sand or finer in the fine earth fraction.
(7) Has less than 5 percent by volume that shows rock structure.

Key to Soil Orders

A Histosols
B Spodosols
C Other soils that:
Have an oxic horizon within 2 m of the soil surface but do not have a plaggen epipedon and do have an argillic or natric horizon above or below the oxic; or meets one of the following requirements:
  (a) If underlain by an argillic or natric horizon, the oxic horizon extends to a depth of more than 1 m from the soil surface.
  (b) If underlain by a lithic or paralithic contact within 75 cm of the soil surface, the oxic horizon extends to this contact.

Key to Suborders

(Note: This key is modified from the original on page 323 of Soil Taxonomy. New suborders are underlined.)

CA Oxisols that have one or both of the following characteristics:
  (1) Plinthite that forms a continuous phase within 50 cm of the mineral surface of the soil, and the soil is saturated with water within this depth at some time during the year; or
  (2) Either are saturated with water at some time during the year or are artifically drained and also have one or both of the following characteristics associated with wetness:
    a. A histic epipedon; or
    b. If free of mottles, immediately below any epipedon that has moist color value of less than 3.5 there is a dominant chroma of 1 or less; or if there are distinct or prominant mottles within 50 cm of the soil surface, the dominant chroma is 3 or less.

Aquox

CB Other Oxisols that have a torric moisture regime.

Torrox

CC Other Oxisols that have a zero or positive delta pH in some subhorizon of the oxic within 1.5 m of the soil surface.

<u>Acrox</u>

CD Other Oxisols that have either an umbric epipedon or an ochric epipedon that has greater than 1 percent carbon in all subhorizons to a depth of 75 cm or more below the mineral soil surface.

Humox

CE Other Oxisols that have an ustic soil moisture regime.

Ustox

CF Other Oxisols.

Orthox

Key to Great Groups

Tentative great groups of Aquox

CAA Gibbsiaquox
CAB Plinthaquox
CAC Paleaquox
CAD Eutraquox
CAE Melanaquox
CAF Haplaquox

Tentative great groups of Torrox

CBA Gibbsitorrox
CBB Paletorrox
CBC Eutrotorrox
CBD Haplotorrox

Key to great groups of Acrox (All new great groups.)

CCA Acrox that have a sombric horizon.

Sombriacrox

CCB Other Acrox that have within 1.5 m of the surface sheets that contain 30 percent or more gibbsite or a subhorizon that has 20 percent or more by volume gravel-size aggregates that contain 30 percent or more gibbsite.

Gibbsiacrox

CCC Other Acrox that have within 1.5 m of the soil surface more than 20 percent by volume of petroplinthite, or a lithoplinthic horizon or a petroferric contact.

Paleacrox

CCD Other Acrox that do not have an anthropic epipedon and have a base saturation of 35 percent or more (by NH_4OAc) in the epipedon and in all subhorizons to a depth of 1.5 m.

Eutracrox

CCE Other Acrox that have a Munsell value and chroma (moist) of 4 or less in all subhorizons of the oxic to a depth of 1.5 m from the soil surface.

Melanacrox

CCF Other Acrox.

Haplacrox

Tentative great groups of Humox

CDA Sombrihumox
CDB Gibbsihumox
CDC Eutrihumox
CDD Melanohumox
CDE Haplohumox
CDF Rhodohumox

Tentative great groups of Ustox

CEA Sombriustox
CEB Gibbsiustox
CEC Paleustox
CED Melanaustox
CEE Rhodustox
CEF Haplustox

Key to great groups of orthox   (New great groups are underlined.)

CFA Orthox that have a sombric horizon.

Sombriorthox

CFB Other Orthox that have within 1.5 m of the surface sheets that contain 30 percent or more gibbsite or a subhorizon that has 20 percent or more by volume gravel-size aggregates that contain 30 percent or more gibbsite.

Gibbsiorthox

CFC Other Orthox that have within 1.5 m of the soil surface more than 20 percent by volume of petroplinthite, or a lithoplinthic horizon or a petroferric contact.

<u>Paleorthox</u>

CFD Other Orthox that do not have an anthropic epipedon and have a base saturation of 35 percent or more (by NH_4OAc) in the epipedon and in all subhorizons to a depth of 1.5 m.

Eutrorthox

CFE Other Orthox that have a Munsell value and chroma (moist) of 4 or less in all subhorizons of the oxic to a depth of 1.5 m from the soil surface.

<u>Melanorthox</u>

CFF Other Orthox that have a Munsell hue of 5YR or redder in all subhorizons of the oxic to a depth of 1.5 m from the soil surface.

<u>Rhodorthox</u>

CFG Other Orthox that have a Munsell hue of 10YR or redder in all subhorizons of the oxic to a depth of 1.5 m from the soil surface.

<u>Xanthorthox</u>

Circular Letter No. 2, May 1978

This letter was very brief, pointing out that we would have time for discussion in Malaysia and Thailand at the Second International Soil Classification Workshop. A potential meeting at the International Soil Society seminar in Edmonton, Canada, was proposed.

Circular Letter No. 3, December 1978

Although the Malaysia/Thailand Workshop (see References to Additional ICOMOX Activities) had served as a forum to discuss the problems in Oxisol classification, there was a real need for hard facts upon which to base future discussions.

In Circular Letter No. 3, it was reported that ICOMOX was formally recognized by the USDA and that the Committee would soon be formulated and the members notified of their selection. Although it was apparent that a better working definition to separate Ultisols and Alfisols from Oxisols was paramount, the feeling was that this could not be done until ICOMLAC had progressed further in its charge. Because the ICOMLAC had been operating for some years, it was decided to focus discussion on features clearly within the Oxisol order. Also there was concern about how the Oxisols should be defined in relationship to the proposed order Andisols (Smith 1978).

The following, reprinted from Circular Letter No. 3, illustrates some of the major concerns of the group.

Discussion

Definition of Oxic Horizon

Thickness requirement

The proposal is to increase the present 30 cm thickness requirement to 50 cm. The basis for the proposal is that, particularly in udic to perudic moisture regimes, a horizon just under the A or Ap, which meets all the requirements for an oxic and is about 30-50 cm thick but which is underlain by a distinct argillic, is frequent. Many times these soils also have the clay increase requirement for an argillic horizon, but if the soil is keyed out it is classified as an Oxisol. However, from a management point of view, the soil is more akin to Oxisols. Increasing the thickness requirement will bring these soils into Paleudults, which is a more appropriate placement, according to the Malaysians.

In view of the proposed changes in the LAC soils (ICOMLAC proposals), this change may be unnecessary. The final proposal will depend on the concept of the Kandi great group.

Charge characteristics

It is proposed that the CEC NH_4OAc pH 7 be retained but the ECEC be increased to 12 meq from the present 10 and the oxic horizon meets both requirements.

An additional suggestion is to make the definition of change on an organic-matter free basis using the mathematical procedure of Bennema. The accuracy of this procedure was questioned, and it was also pointed out that organic matter is so intimately bonded with the mineral colloids that it is impossible or impractical to allocate the charge to the organic and mineral fractions. Further, in Soil Taxonomy, the low charge of oxic horizons includes any contribution from organic matter. The chairman proposed that Sombroek and

Bennema prepare the graphical procedure for allocating CEC and, after testing on a wider range of soils, submit the results for further discussion.

Considerable dissatisfaction was expressed over the methods now available for charge determination, and the need for alternative approaches was stressed. The papers of Uehara and Gillman at this meeting are particularly relevant.

*pH in 1*N *NaF*

A new criterion, that oxic horizons have a pH of less than 9.4 in 1*N* NaF, was generally accepted. This was introduced to separate oxic horizons from the yet to be defined andic horizon or Andisols.

The need for this criterion became apparent when the Tha Mai series (T14, Thailand) was examined. The soil has many morphological and mineral-chemical properties of an Andisol except that the pH in 1*N* NaF is between 7.5 and 8 in the major part of the control section.

Weatherable minerals

Dissatisfaction with the present definition was expressed, but few specific alternatives were proposed. However, several important points were raised, which could be formulated later as a proposal.

First, that the amount and type of weatherable minerals was not as important as the weathering stage of these minerals. An estimate of the latter could be made by determining the amount of total bases (Ca, Mg, Na, and K) by employing a hot 6*N* HCl extract. (This procedure is used in Malaysia for evaluating the nutrient-supplying power of the soil, and crop needs are evaluated on this.) The method must be tested and limits defined. The total base status may be a subsidiary requirement in the definition of weatherable minerals.

Lower particle-size limit

The proposal is "has a texture of loamy fine sand or finer in the fine earth fraction and has more than 6 percent clay." There was a general consensus of opinion on this proposal. The silt/clay ratio (proposed in 1959 by van Wambeke) was suggested as a possible additional requirement. Van Wambeke indicated that it may be more appropriate for defining some kind of subgroups. It was also pointed out that in soils high in gibbsite, the weathering trend of the silt/clay ratio may be upset as gibbsite tends to crystallize in the fine silt fraction.

Rock structure

The proposal reads, "has less than 5 percent by volume that shows rock structure unless the rock relicts are coated with gibbsite or iron, or both." There were few disagreements to the modifications.

Key to Soil Orders

There was considerable discussion on situations where the oxic horizon is present above or below an argillic horizon. Sys gave examples of such cases in Zaire. Bennema, however, had doubts on the accuracy of such evaluations in the field; i.e., it is always difficult to determine where an oxic ends and an argillic begins. This point was further amplified in the discussion in Thailand.

Much of the discussions overlap with those of ICOMLAC, and there was a general feeling that the definition of an Oxisol depends on the concepts being formulated for the LAC soils. Consequently, the discussions were postponed to the Thai part of the workshop.

There was, however, a general agreement that the requirement of plinthite be dropped in the definition of Oxisols.

Key to Suborders

Changes were only proposed in definitions of some suborders, and no suborders were eliminated or new ones added.

Aquox

It was proposed and generally accepted that the plinthite requirement be dropped from the definition of the Aquox. The suborder now reads:

> Either are saturated with water at some time during the year or are artificially drained and also have one or more of the following characteristics associated with wetness:
> a. A histic epipedon; or
> b. If free of mottles, immediately below any epipedon that has moist color value of less than 3.5 there is a dominant chroma of 2 or less; or if there are distinct or prominent mottles within 50 cm of the soil surface, either the dominant chroma is 2 or less, or the hue is 2.5 or yellower.

Humox

Most people appeared happy that the organic carbon requirement was dropped. There was serious disagreement on the use of temperature at this high level as, especially Buol feels, this is a family level criterion. The Humox brings together all the mountain Oxisols, the unifying feature being the low temperatures at high elevations. If the temperature requirement is dropped, Sys feels that some of the low-elevation soils, such as the Kalahari sands, may be included in this suborder and this is undesirable. Arnold proposed that we look for alternative criteria. The present definition of the Humox is:

> Other Oxisols that have either an umbric epipedon or an ochric epipedon that has more than 1 percent carbon in all subhorizons to a depth of 75 cm or more below the mineral soil surface, and have an isothermic, thermic, or cooler soil temperature regime.

Ustox, Torrox, Orthox

There were no changes in definitions.

Xerox

Isbell thought there might be a need for provision of the Oxisols in the xeric moisture regime. The chairman has requested him to give some examples with climatic data, where possible.

Key to Great Groups

Due to insufficient time, this was not discussed in detail. However, some discussions were held during the field trips and, based on this, the following key is presented. The suborder of the Orthox is used as an example.

Key to great groups of Orthox

CEA Orthox that have a sombric horizon.

Sombriorthox

CEB Other Orthox that have, within 1.5 m of the soil surface, sheets that contain 30 percent or more gibbsite or a subhorizon that has 20 percent by volume of gravel-size aggregates that contain 30 percent or more of gibbsite.

Gibbsiorthox

CEC Other Orthox that have a zero or positive delta pH in some subsurface horizon of the oxic within 1.5 m of the soil surface.

Acrorthox

CED Other Orthox that have either an umbric epipedon or an ochric epipedon that has more than 1 percent carbon in all subhorizons to a depth of 75 cm or more below the mineral soil surface.

Umbriorthox

CEE Other Orthox that do not have an anthropic epipedon and have a base saturation of 35 percent or more (by NH_4OAc) in the epipedon and in all subhorizons of the oxic to a depth of 1.5 m from the soil surface.

Eutrorthox

CEF Other Orthox that have a value and chroma (moist) of 4 or less in all subhorizons of the oxic to a depth of 1.5 m from the soil surface.

Melanorthox

CEG Other Orthox that have a hue of 5YR or redder in all subhorizons of the oxic to a depth of 1.5 m of the soil surface.

Rhodorthox

CEH Other Orthox that have a hue of 10YR or redder in all subhorizons of the oxic to a depth of 1.5 m of the soil surface.

Haplorthox

CEI Other Orthox.

Xanthorthox

Circular Letter No. 4, May 1979

By this time the International Committee on Andisols (ICOMAND) had been established under the chairmanship of Mike Leamy, and ICOMLAC had progressed through 11 circular letters. There was major concern over the definition of the Oxisol order, and Circular Letter No. 4 reproduced the minutes of an informal meeting held in Ghent. A couple of points that will be of note for future deliberation of ICOMOX are the use of "Akr" instead of "Acr," the troublesome nature of the Humox suborder, and consideration given the total elemental analysis, criteria long used in other soil classification schemes but largely avoided in Soil Taxonomy.

Minutes of the Informal Meeting held at Ghent, 21st December 1978

Members present: Drs. J. Bennema, H. Eswaran, F. Moormann, W. Sombroek, C. Sys, and R. Tavernier

Report

Frank Moormann presented a summary of the progress of ICOMLAC. The details of this are to be found in ICOMLAC Circular Letter No. 11.

Much of the rest of the discussion was devoted to matters of ICOMOX. The major points raised are the following:

1. Correction of CEC due to organic matter.
   Bennema proposed the possibility of having a correction for CEC due to organic matter in the definition of the oxic horizon. Some of the points related to this include:
   a. There is no fixed coefficient that could be applied, as the contribution of organic matter varies from soil to soil. The graphical approach is commendable, but is such a procedure worthwhile?
   b. From a management point of view, it does not matter too much if the high CEC is due to the mineral colloid or the organic matter.
   c. It was suggested that Bennema present some proposals with alternatives.
2. Zero point of net charge (ZPNC).
   With an increasing amount of work on this, it would be a parameter for inclusion in the Oxisols. As ZPNC correlates well with delta pH, extractable sulfates, and anion fixation, soils could be defined on ZPNC. Delta pH is a good estimate and may be used to define Acri- great groups or suborders.
3. Is the sombric horizon significant?
   a. It has been reported in Sri Lanka, Kenya, Brazil, and Zaire.
   b. In Zaire, such soils occupy about 100,000 ha and are considered poor soils.
   c. It is necessary to undertake a detailed study on these soils.
   d. Sombri- great groups should *not* be eliminated from the classification.

4. Use of temperature restriction in Humox.
   a. In the absence of such a restriction, soils like Nipe (Typic Acrorthox), which have high organic carbon but also a high C/N ratio, will be included. Guy [Smith] suggested that it may be useful to test total N instead of C.
   b. The present definition gives a geographic delineation—at high elevations. Most Humox are also in udic to perudic areas.
   c. There are few other parameters to differentiate these soils.
   d. Use of the humic attribute at the great group level was also considered but eliminated because it did not give the desired geographic distribution.
5. Much of the rest of the discussion was confined to points raised by Bennema. Some of these are:
   a. We should identify the problem areas and suggest solutions before classifying the Oxisols.
   b. ICOMLAC should finalize their decision and ICOMOX could then follow up.
   c. Several alternative methods of CEC can be used to define the oxic horizon.
   d. Bennema then tabled a tentative proposal for the great groups of the Orthox:
      i. Soils coarser than fine sandy loam.

         Psammorthox

      ii. Other soils with a SiO_2/Al_2O_3 ratio of the fine earth of less than 0.75 or a SiO_2/R_2O_3 of less than 0.55.

         Sesquiorthox

      iii. Other soils with a base saturation (NH_4OAc) of 35 percent or more (or a pH of 5.2 or more) in all horizons.

         Eutrorthox

      iv. Other soils with more than 18 percent Fe_2O_3 in the fine earth fraction.

         Ferriorthox

      v. Other soils with an umbric epipedon.

         Umbriorthox

      vi. Other soils with a SiO_2/Al_2O_3 ratio of less than 1.7 and low iron content (less than 9 percent, or a sliding scale may be necessary).

         Oliorthox

      vii. Other soils.

         Haplorthox

(Your comments on this proposal are solicited.)

Summary of Properties of the Oxic Horizon

The oxic horizon is an endopedon[a] that:

1. Does not meet the clay increase requirements of an argillic or kandic horizon,[b]
2. Is at least 50 cm thick,
3. Has an effective CEC of 12 meq per 100 g clay[c] or less,
4. Has a CEC by NH_4OAc of 16 meq per 100 g clay or less (unless there is an appreciable content of aluminum-interlayered chlorite[d]),
5. Has a pH in 1*N* NaF (1:50) of less than 9.2 after 2 minutes continuous stirring,[e]
6. (Weatherable mineral requirement, yet to be defined),
7. Has textures of sandy loam or finer in the fine earth fraction,
8. Has less than 5 percent by volume that shows rock structure unless the rock relicts are coated with gibbsite or iron, or both.

Footnotes

a. A proposal of Sombroek (Wim should make a descriptive definition of the endopedon).
b. Frank [Moormann] has suggested a "finer textured subsurface horizon" (ICOMLAC Circular Letter No. 11). He may want to define a kandic horizon as a special kind of argillic. As the Oxisols are keyed out earlier, we may need this first clause to be sure that we do not bring in the Kandisols. This addendum will also take into consideration the proposal of Bennema-Comerma for defining the oxic.
c. Effective CEC is bases plus KCl aluminum. Charge characteristics are calculated on measured clay or 15-bar water x 3, whichever value is higher but not more than 100.
d. We have encountered aluminum-interlayered chlorite in some Oxisols of Zaire. Typically there is a 14Å peak, which does not shift on glycolation or heating but which may increase in intensity toward the soil surface.
e. This limit is to exclude Andisols. Once Mike [Leamy] has decided on the exact number, we can follow accordingly. Also if ECDAM [exchange complex dominated by amorphous material] is finalized, we can include this.

An Akroxic Horizon

Wim Sombroek has pointed out that for semantic reasons, it is better to have Akr (= end of stage) instead of Acr (Acer = acid, as in Acrisols). I accept, with thanks.

It has also been suggested that we could consider an akroxic horizon as a special kind of oxic horizon.

An akroxic horizon has, in addition to all the properties of the oxic horizons, the following:

1. Has more than 40 percent clay in the major part of the endopedon to a depth of 1.25 m from the soil surface;
2. Has less than 30 percent gibbsite in the fine earth fraction;
3. Has a delta pH of –0.25 or more positive in the major part of the endopedon to a depth of 1.25 m from the soil surface.

Circular Letter No. 5, January 1980

Insufficient material had been received to summarize, so Circular Letter No. 5 was devoted to a report on the *Project de Classification des Sols*, an effort by the French pedologists of ORSTOM under the leadership of P. Segalen. The discussions, including comments by Guy Smith, R. Tavernier, C. Sys, and Hari Eswaran on how the objectives of the proposed French System compared to Soil Taxonamy, are interesting but not directly related to the objectives of ICOMOX so are not reproduced here.

Circular Letter No. 6, August 1980

By this time, ICOMOX chairman Eswaran had moved from Ghent to Washington, D.C., to head up the Soil Management Support Service (SMSS). Plans were being made to conduct the Fourth International Soil Classification Workshop in Africa in 1981. This workshop, in conjunction with ICOMAND and ICOMLAC would focus on the order level separation of Oxisols, Andisols, and soils with argillic horizons, primarily the Alfisols and Ultisols. Of particular interest to the concerns within Oxisols was the opportunity to study sombric horizons.

A first draft of a rewrite of the Oxisol chapter was presented by chairman Eswaran to solicit comments from the Committee before preparing a working document to be used during the Rwanda meeting. Since an edited and slightly revised version is presented in Circular Letter No. 7, this first draft is not reproduced here.

Circular Letter No. 7, May 1981

Circular Letter No. 7 provided the basis for discussions and testing at the Rwanda soil classification workshop (see References to Additional ICOMOX Activities).

In addition to noting the general format proposed, the reader should take special note of the sombric horizon definition and the akric soil materials definition. An extensive list of proposed subgroups is presented.

For the special concerns of ICOMOX, chairman Eswaran printed the response Guy Smith made to the nine questions about Oxisols and Oxisol-like soils and their classification. Both the draft of the Oxisol chapter for the Rwanda Workshop and Smith's interview were reproduced in this letter.

Oxic Horizon

The oxic horizon is intended to characterize a mineral subsurface horizon in an advanced state of weathering. It is an altered subsurface horizon of at least 50 cm (20 inches) thick. The colloid fraction is dominated by kaolinite with or without iron and aluminum oxhydrates and with few or no other layer lattice minerals including halloysite and meta-halloysite; allophane if present is in very small amounts, although other resistent minerals such as rutile, magnetite, or anatase may also be present in traces in the colloid fraction. The silt and sand fraction of the oxic horizon is generally dominated by quartz with some of the resistent minerals. Muscovite may be present in the coarser fractions but may not exceed more than 10 percent of the 20-200 micron fraction. Other weatherable minerals, which are potential sources of nutrients (K, Mg, Ca), may only be present if they do not exceed 1 percent of the 20-200 micron fraction. Rock fragments or lithorelicts may only be present if they are coated with sesquioxides or if they are completely altered.

The stipulation placed on the colloid composition ensures that the horizon has a low cation-exchange capacity. The CEC by 1*N* NH_4OAc (CEC 7) is less than 16 meq per 100 g clay, and the effective CEC (ECEC), as determined by the sum of NH_4OAc bases and 1*N* KCl-extractable aluminum is less than 12 meq per 100 g clay. These charge characteristics ensure that soil materials with low-activity clay but with high organic-matter content are excluded. The mineralogy and charge characteristics also exclude horizons contaminated with ash and, to separate the andic materials, oxic horizons do not have a pH higher than 9.4 in 1*N* NaF. Some horizons may have high amounts of low-charge illite, but as these soils generally also have high amounts of muscovite in the silt and sand fractions, they are excluded from oxic horizons. Similarly, horizons with pyrophyllite, a mineral with practically no permanent charge, are also excluded from the oxic horizon.

This upper boundary of the oxic horizon may be the soil surface, if the profile is truncated, or the lower part of the Al or Ap horizon, to meet the mineralogical and charge characteristics of the oxic horizon. The lower boundary is set again by the mineralogical and charge requirements and, in addition, by the presence of saprolite, if this is evident, by material that shows rock structure, or by a horizon that has significant

amounts of clay skins and at least 1.5 percent of the area of thin sections is occupied by illuviation argillans. The oxic horizon itself has less than 1.5 percent by area of illuviation argillans.

Significance to Classification

The most important attribute of the oxic horizon is that it is almost devoid of primary weatherable minerals. The second important attribute is that in many oxic horizons, despite being high, the clay content is also constant, with depth indicating little or no mobility in the soil. This suggests a high order of stability or immobility of the clay fraction, which has been attributed to cementation by sesquioxides or binding by organic matter. In addition, the horizon has only traces of water-dispersable clay unless it has a net positive charge.

A third attribute, which is related to the nature of the colloid, is the inability of the clay particles to pack themselves into larger blocky structural entities. Macro-structure may be angular or subangular blocky, but the grade of structure is generally moderate to weak; the peds fail abruptly under gentle pressure between thumb and finger. The consistence is generally very friable. Lack of clay skins may be related to these properties.

These and other attributes directly or indirectly influence the performance of the soil. The very low cation-exchange capacity is an important limitation to soil management. In addition, some oxic horizons have a high capacity to fix and make unavailable some anions, particularly phosphates. Calcium and potassium may be specifically limiting in some soils with an oxic horizon. The bases on the exchange complex are replaced by aluminum with consequent detrimental effects on plant growth. In many soils with an oxic horizon, any significant nutrient-holding capacity and total nutrient content is confined to the organic-rich surface horizon, if this is present. Clearing of the natural vegetation and burning may destroy this critical storehouse.

Although, in general, oxic horizons are clayey, the colloid composition is such that it tends to aggregate and form pseudosilts and -sands. The consequent effect is to reduce the available water-holding capacity of the soil. Even in humid environments, plants may show signs of moisture stress after a few rainless weeks. Yields of deep-rooted trees, such as rubber and oil palm, are known to decline due to moisture stress. In addition, these aggregates are also hydrophobic and are not easily wetted. Nutrients may be stored within the aggregates but are not available to the root hairs as they do not penetrate them.

In other soils, a clay increase with depth is a desirable characteristic because the subsoil with the higher clay content can store more moisture, while the lighter textured surface soil is suitable for root penetration and cultivation. However, if the subsurface horizon is oxic and even if the surface horizon is lighter textured, the soil does not show the same beneficial effects. The rapid permeability of the oxic horizon, its low water-holding capacity, its low nutrient-holding capacity, and its low nutrient-supplying power override the textural increase that is such a favorable attribute in Ultisols and Alfisols. For this reason, less emphasis is placed on the clay distribution in soils with an oxic horizon.

In subhumid and arid climates, leaching and the hazards of base depletion may initially be less critical. Moisture stress is the main limiting factor, which can be corrected, however, through irrigation. Even with irrigation, the other limiting factors of the oxic horizon still remain. Consequently, even in the drier environments, the oxic horizon is significant.

It is considered that a taxonomy which does not reflect these properties will have limited value. Consequently, the oxic horizon is being given priority over some other horizons, particularly the argillic horizon.

Oxic Horizon Definition

In summary, the oxic horizon is a subsurface horizon that:

1. Is at least 50 cm thick unless there is a lithic or paralithic contact within 50 cm of the soil surface, then it is at least 30 cm thick;
2. Has a fine earth fraction that has less than 12 meq of bases extractable with 1*N* NH_4OAc plus aluminum extractable with 1*N* KCl per 100 g clay;
3. Has an apparent CEC of the fine earth fraction of 16 meq or less per 100 g clay by 1*N* NH_4OAc unless there is an appreciable content of aluminum-interlayered chlorite;

4. Has a pH in 1*N* NaF (1:50) of less than 9.4;
5. Does not have as much as 1 percent of weatherable minerals containing Ca, K, or Mg, or 10 percent of muscovite in the 20-200 micron fraction;
6. Has a texture of sandy loam finer in the fine earth fraction and has more than 8 percent clay;
7. Has mostly gradual or diffuse boundaries between its subhorizons and adjacent horizons;
8. Has less than 5 percent by volume that shows rock structure unless the lithorelicts are coated by sesquioxides.

Sombric Horizon

The Geomorphic Setting in Rwanda

Rwanda is a country of contrasting landscapes ranging from recent volcanic soils to surfaces that could be dated to end- and mid-Tertiary. Several peneplanation levels may be recognized and deserve a detailed geomorphic study. Most of the surfaces are heavily dissected, which results in narrow plateaus with rather steep slopes. The soil temperature regime is isothermic and, in most of the country, the soil moisture regime is ustic.

The important feature of the soils on these old surfaces is that they have been considerably reworked. Stone lines of quartz or petroplinthite in the soil point to this *remanie* feature. However, if the parent material of the original soil does not contain quartz or petroplinthite, the allogenic nature of the soil is not evident. In some soils developed on schistic or gneissic materials, there is yet another feature, which is referred to as *polyedres* in the local profile descriptions. These are rounded bodies, about 2 to 3 cm in diameter, and very compact. Some of them have cutans, although most do not. Neel considers them an indication of the stone line. They frequently accumulate at the transition horizon to the saprolite in the present day profile. They may also be present in the zone of the stone line, if a stone line is present, or may act as the stone line. Some are characteristically redder than the surrounding s-matrix, which in the present day profile is enriched with organic matter. The matrix of the *polyedres* is similar to that of the underlying saprolite or C horizon but differs distinctly from the solum material. A second variant, also observed in Rwanda, is where the matrix of the *polyedres* is black and clearly indicates that they are relicts from former humus-rich horizons. A third variant is the clay balls observed in many Oxisols in Brazil, Malaysia, and Thailand where the matrix of the clay balls and the enclosing material are similar, except that the clay balls are very compact. We know little about the genesis and significance of the clay balls or *polyedres*.

As the term *polyedres* is not descriptive in English, the term "pedovites" is tentatively proposed for these features and defined as:

> Pedovites are rounded to subrounded distinct entities, which show little or no differentiation in their internal matrix but may be contrasting with respect to the enclosing soil material. Their sizes may vary from less than 1 to more than 5 cm in diameter. They are generally very compact with a bulk density more than 1.8. Some may contain relict cutans or other relict features such as weatherable minerals, although the enclosing soil material may be free of these.

Pedovites are relevant for the genetic evaluation of the soil but their significance to classification needs to be studied. In the French Classification (CPCS 1967) the reworked aspect of the soil is considered, but this is not used in Soil Taxonomy as it is the result of geomorphic rather than pedogenic processes. The pedovites in some of the soils we have seen in Brazil, Malaysia, and Thailand during the international soil classification workshops are most probably authigenic, while those in Rwanda are distinctly allogenic.

Origin

The view of some Rwandese pedologists is that the sombric horizon is a relict horizon or it is a buried A horizon. This is contrary to the earlier views of the pedologists of INEAC working in the 1950s in Zaire, on which the description in Soil Taxonomy is based. The earlier opinion on the genesis of the sombric horizon is that it is an illuvial horizon formed by the accumulation of humus. An initial stage is

the coating of ped faces. The humus does not penetrate the ped interiors, which are redder in color. The layer is speckled and has a polka dot appearance. Tongues of the humus may also be seen penetrating the soil material. It was supposed that the polka dots and the tongues grew by accretion, resulting finally in a dark and continous horizon. These early observations are correct, but the interpretation with respect to genesis has never been established. Other observations on the sombric horizon include:

a. The sombric horizon seems to occur at the stone line or engulfs the stone line.
b. If no stone line of quartz or petroplinthite is present, a discontinuity in the material may be established by comparing the fine/coarse sand ratios in the soil.
c. The discontinuity may also be shown by the presence of the reddish or black pedovites.
d. The horizon is absent on recent surfaces.

Morphology

The sombric horizon shows several forms determined by the position of the soil in the present landscape and the geomorphic processes that have acted on the landscape. The soil temperature regime is isothermic and grading to isomesic at higher elevations. Consequently, formation of a humus-accumulative horizon is a current active process. This presents additional problems in identifying some sombric horizons where the present umbric or mollic epipedon merges with the underlying sombric.

In the modal profile, the sombric is clearly seen as a distinct subsurface horizon separated from the surface umbric epipedon by a lighter colored horizon. The vegetation is usually a grass (*Eragrostis blepharoglumes*), which produces a sod about 10-15 cm thick, compact, and extremely resistent to erosion. The Russians will call it a *derno* layer. The subsurface horizon is oxic. The sombric horizon is weak, angular blocky to massive. In other pedons, it is slimy and sticky, but very friable and with a very low bulk density.

The soil may have an argillic horizon, which may lie over the sombric or incorporate it. In many cases, the clay skins in the sombric appear to have less organic matter and suggest that illuviation is post-sombric. In the few soils with argillic horizon that were observed, though there are clay skins in the sombric, the grade of structure, consistence, and other physico-chemical properties of the horizon are clearly oxic. It appears that clay translocation is more recent, i.e. post-sombric and post-oxic. As stated earlier, if the parent material can provide stones or pedovites, these are generally present in the lower part of the sombric.

The sombric also has other chemical characteristics especially in comparison to the adjacent horizons. In the modal profile, there is a distinct increase in carbon, calcium CEC, and phosphorus when compared to the overlying or underlying horizon. On old road cuts, the sombric horizon stands out clearly as it is covered preferentially with moss or grasses.

A second variant is where the sombric is formed by tongues of humus-rich material penetrating the soil. In profiles with this kind of sombric, the tongues are clearly formed by former root channels which have been invaded by humus. In such profiles, the sombric is the remnant of a former umbric or mollic epipedon which has been truncated through erosion with a subsequent deposition of more recent materials on the surface.

In the third variant, the sombric is not so distinct as it merges with the overlying umbric epipedon. More complex forms may be present. The sombric may consist of just the black pedovites. The situation is further complicated if the black pedovites are present in the lower part of the present-day umbric epipedon.

Significance to Taxonomy

If the sombric horizon is treated as a buried horizon, most of these soils will be classified as "Thapto sombri . . ." There are some soils, however, where it is difficult to establish the fact that it is a buried horizon.

My [Eswaran] personal opinion is that, irrespective of the fact that it is buried or not, it is one of the more striking features of these soils. As profile morphological differentiation is in general poor in soils in the tropics, the sombric serves a useful purpose. It is one of the properties useful to the surveyor and can

be used to define mapping units as has been done in the INEAC system. Further, the presence of a sombric horizon is an important management-related property. The presence of this layer in the highly weathered and leached soils of the tropics makes the soil potentially more fertile than it could be: The layer having a higher CEC can store more nutrients than if it was absent. Consequently, my recommendation is to retain its use in Soil Taxonomy.

Definition and Use in Soil Taxonomy

The following is a tentative proposal for the sombric horizon:

The sombric horizon is a subsurface horizon which meets the color and organic carbon requirements of an umbric or mollic epipedon. If it is present as a continous layer, it is at least 20 cm thick and the Munsell color value and chroma is at least 1 unit lower than the overlying horizon. If it is present as tongues of humus-rich material or as discontinuous patches, the tongues or patches occupy at least 20 percent of the volume of the layer and, in addition, meet the color and organic-matter requirements stipulated previously. If it is present as pedovites, the pedovites occupy at least 20 percent of the volume of the layer and meet the color and organic-matter requirements stipulated earlier.

To be significant for classification and to be used at the great group level, the sombric horizon is present within 1.25 m of the soil surface. When present at greater depths, it may serve as a subgroup characteristic. In Rwanda, it is present in Inceptisols, Alfisols, Ultisols, and Oxisols. The sombric horizon is not provided for in the Alfisols in Soil Taxonomy as it was thought that they generally have a base saturation of less than 50 percent (CEC 7). In Rwanda such soils are present and are currently classified as Ultic Haplustalfs, but a classification as an Ultic Sombriustalf is considered more appropriate.

Akric Soil Materials

Akric soil materials are mineral soil materials that have at least 35 percent clay and an effective cation-exchange capacity (ECEC) as determined by the sum of bases (extracted with 1*N* NH_4OAc) and aluminum (extracted with 1*N* KCl) of less than 1.5 meq per 100 g clay[1] and delta pH (pH KCl –pH H_2O) of –0.2 or more positive. In addition, the soil material meets all the requirments for an oxic horizon.

Akric soil materials are a result of intensive weathering. The soil is practically devoid of primary weatherable minerals. Weathering and mineral alteration have resulted in a colloid dominated by sesquioxides and, in this respect, soils with akric materials are considered at a more advanced stage than these with the normal oxic horizon. The permanent negative charge of these materials may be counterbalanced or exceeded by the permanent positive charge. The soils have a high zero point of net charge (ZPNC), and the pH where the variable net surface charge is zero (pH) is also high, both being in the region of 5.0 to 6.5. The variable negative charge (CEC sum of cations) may be ten to twenty times higher than the ECEC, the latter being an estimate of the permanent charge.

The low effective cation-exchange capacity is due to a low amount of aluminosilicate clay minerals including kaolinite. The colloid fraction has a very high amount of iron oxyhydrates or oxides such as goethite or haematite. Significant amounts of gibbsite may be present, but the presence of a dominance of gibbsite alone without the iron oxhydrates does not give rise to akric soil materials. The high iron oxhydrates are necessary to give, in addition to the low charge, the high variable charge and the accessory properties of anion fixation, etc.

It is not impossible for akric soil materials to have clay skins or illuviation argillans. Even with a net positive charge, clay may move but the adverse physico-chemical properties of the soil material are considered more important than a textural increase in the soil.

Soils with akric soil properties are some of the poorest soils in the world. They have several adverse characteristics, including low to very low nutrient levels, imbalance between nutrient cations, deficiencies and toxicities of certain trace elements, a very low water-holding capacity, and a tendancy to fix high amounts of phosphates.

1. An estimate of percent clay using 15-bar water times 2.5 could be substituted if poor dispersion is suspected.

Soils with akric soil materials represent the extreme state of weathering. Although morphologically they look like ideal soils for cultivation, their limitations are so serious that it is better to leave them under natural vegetation. It is felt that these properties must be recognized and identifed at a high taxonomic level, as in the case of sulfidic materials in Entisols.

Oxisols

Oxisols are the reddish, yellowish, or grayish soils of tropical and subtropical areas. They frequently occur on surfaces of great age and have mostly gentle slopes. Many are preweathered and formed on materials that have been transported. Some are formed directly on rock, which is frequently basic or ultrabasic in composition.

Apart from a thin, organic-rich surface horizon, Oxisols are in general featureless soils. There is practically no variation in color or texture with depth. At high elevations or in cooler climates, the surface organic-rich horizons may thicken considerably. Those Oxisols formed on transported materials may have a stone line indicating discontinuity in the material. In some Oxisols on the older surfaces, and particularly those occurring at high elevations, a dark subsurface horizon called the sombric horizon, may be present. Apart from these soils, the subhorizons in most Oxisols are not distinct, and differences in properties with depth are so gradual that horizon boundaries are generally arbitrary.

Weathering and soil formation has reduced the material to a mixture of quartz, 1:1 aluminosilicate clay minerals, free oxides, and some organic matter. Minerals that can weather to release nutrients such as Ca, Mg, and K are negligible. At an extreme state of weathering and soil formation, the soil material is composed of inerts such as quartz, rutile, and ilmentite and oxides and oxyhydrates of iron and aluminum.

Without amendments and due to the specific mineralogical composition, most Oxisols have low productivity for cultivated plants. The basic limitation is not only chemical but also physical. In the absence of gravel, the soils are easy to cultivate but they have very low available water and a high hydraulic conductivity. The rapid permeability may in one sense also be an advantage, as when combined with the gentle slopes on which these soils occur, they became extremely resistant to erosion. Some Oxisols fix anions, such as phosphates, making them unavailable to plants.

With good management, many Oxisols are very productive. They are generally suited for a plantation type of agriculture. If climatic conditions are favorable, rubber (*Hevea brasiliensis*) and oil palm (*Elais guinensis*) are ideal crops. When there is a dry season, sugarcane does well under good management conditions.

The largest extent of Oxisols is in the Amazon basin in South America and in central Africa—in Zaire, Rwanda, and Burundi. Oxisols also occur sporadically in other parts of Africa—in Kenya, Tanzania, Uganda, Madagascar, Zambia, and Zimbabwe. On the west coast of Africa, Oxisols extend from Senegal in the north to about Angola in the south. In Asia, the surfaces are much younger and the largest extent is in Kalimantan, Indonesia. In most of Asia, the Oxisols are formed *in situ* on highly weatherable preweathered and transported deposits. Other sporadic occurrences include the Caribbean Islands and the islands of the Pacific, including Hawaii. These Oxisols are similar to the Asian ones.

Definition of Oxisols

Oxisols are mineral soils that meet one of the following two requirements:

1. Have akric soil materials, the upper boundary of which is within 75 cm of the mineral soil surface.
2. Have an oxic horizon, the upper boundary of which is within 1.25 m of the soil surface and that either:
   a. Contains more than 35 percent clay in all parts after mixing to a depth of 18 cm, or
   b. Has less than 35 percent clay in all parts after mixing to a depth of 18 cm and does have any of the following overlying the oxic horizon:
      (1) a kandic horizon
      (2) an argillic horizon
      (3) a spodic horizon
      (4) a layer of 50 cm or more thickness with andic materials.

Key to Suborders

CA Oxisols that are either saturated with water at some time during the year or are artificially drained and have one or both of these following characteristics associated with wetness:

a. A histic epipedon, or

b. If free of mottles, immediately below any epipedon that has moist color value of less than 3.5 there is dominant chroma of 2 or less, if there are distinct or prominent mottles within 50 cm of the soil surface, the dominant chroma is 2 or less, or the hue is 2.5Y or yellower.

Aquox

CB Other Oxisols that have akric soil materials within 1.5 m of the mineral soil surface.

Akrox

CC Other Oxisols that have a torric soil moisture regime.

Torrox

CD Other Oxisols that have a mollic or umbric epipedon.

Humox

CE Other Oxisols that have an ustic soil moisture regime.

Ustox

CF Other Oxisols that have an udic or perudic soil moisture regime.

Orthox

Key to Great Groups

Aquox

These are the wet Oxisols. They lie in shallow depressions that are commonly flooded during the rainy season or at the base of slopes where they receive seepage water. Some of these soils have plinthite at shallow depths or have petroplinthic gravel underlain by plinthite. A few may have a petroferric contact at shallow depths.

There are few descriptions of Aquox. They frequently are present in narrow valley bottoms and so are not delineated on small-scale maps. Frequently, they are mistaken for Fluvents or Aquepts, the former due to the physiographic position. Differentiating a Tropaquapt and a Haplaquox in the field is difficult and requires laboratory analysis, particularly mineralogical analyses.

Definition

Aquox are the Oxisols that are saturated with water in the major parts of the oxic horizon during some time of the year. They may have a histic epipedon or have an oxic horizon with the following characteristics associated with wetness:

> If free of mottles, immediately below an epipedon that has moist color value of less than 3.5, there is a dominant chroma of 2 or less; or if there are distinct or prominent mottles within 50 cm of the soil surface, the dominant chroma is 2 or less, or the hue is 2.5Y or yellower.

Key to great groups of Aquox

CAA Aquox that have within 1.25 m of the mineral soil surface sheets that contain 30 percent or more gibbsite or a subhorizon that has 20 percent or more by volume gravel-size aggregates that contain 30 percent or more gibbsite.

Gibbsiaquox

CAB Other Aquox that have within 1.25 m of the mineral soil surface a petroferric contact, or a lithoplinthic horizon, or a subhorizon of at least 25 cm thick that has 20 percent or more by volume of petroplinthic gravel.

Paleaquox

CAC Other Aquox that have plinthite that forms a continuous phase within 1.25 m of the soil surface.

Plinthaquox

CAD Other Aquox that have an umbric or mollic epipedon, or an ochric epipedon that has more than 1 percent carbon in all subhorizons to a depth of 75 cm or more below the mineral soil surface.

Humaquox

CAE Other Aquox.

Haplaquox

Great groups in Aquox

Subgroups	Gibbsiaquox	Paleaquox	Plinthaquox	Humaquox	Haplaquox
Batholithic	X	X		X	X
Eutric		X	X	X	X
Humic	X	X	X		X
Leptic	X	X	X		
Plinthic		X		X	X

Akrox

The Akrox are the Oxisols at the most advanced state of weathering and soil formation. They are devoid of weatherable minerals and the colloid fraction is dominated by oxides and oxyhydrates of iron with subordinate amounts of oxhydrates of aluminum. The iron minerals are in the very fine clay size fraction and are mostly haematite and goethite. Aluminosilicate minerals, mainly kaolinite, if present are mainly in small amounts. Some Akrox may have aluminous chlorite in the clay fraction and some muscovite in the silt fraction.

The soils are generally well to excessively drained. There is little or no variation of particle size with depth. The fine earth has a low effective cation-exchange capacity but a high variable charge. The net charge is also positive.

The soils occupy extensive areas in the Amazon basin, in Zaire, and in Kalimantan, Indonesia. The soil moisture regime is ustic, udic, or perudic. Even in the wetter areas, forests are stunted and vegetation is poor.

Definition

Akrox are the Oxisols that

1. Have akric soil materials within 1.5 m of the soil surface.
2. Are never saturated with water or have chroma as follows.
   a. If there are no mottles, the chroma is 3 or more immediately below any epipedon that has a color value, moist, of 3.5 or less;
   b. If there are mottles below the dark epidedon, the chroma is more than 2, or the hue is redder than 2.5.
3. Do not have a histic epipedon.

Key to great groups of Akrox

CBA Akrox that have a sombric horizon.

Sombriakrox

CBB Other Akrox that have within 1.25 m of the mineral soil surface sheets that contain 30 percent or more gibbsite or a subhorizon that has 20 percent or more by volume gravel-size aggregates that contain 30 percent or more gibbsite.

Gibbsiakrox

CBC Other Akrox that have within 1.25 m of the mineral soil surface a petroferric contact, or a lithoplinthic horizon, or a subhorizon of at least 25 cm thick that has 20 percent or more by volume of petroplinthic gravel.

Paleakrox

CBD Other Akrox that have a weighted average clay content in the upper 30 cm of the soil surface of more than 35 percent and the oxic horizon meets the clay increase requirement of an argillic horizon.

Kurakrox

CBE Other Akrox that have a mollic or umbric epipedon or an ochric epipedon that has more than 1 percent carbon in all subhorizons to a depth of 75 cm or more below the mineral soil surface.

Humakrox

CBF Other Akrox.

Haplakrox

Great groups in Akrox

Subgroups	Sombriakrox	Gibbsiakrox	Paleakrox	Kurakrox	Humakrox	Haplakrox
Aquic	X	X	X	X	X	X
Batholithic	X	X	X	X	X	X
Epiaquic	X	X	X	X		X
Humic	X	X		X		X
Leptic	X	X	X	X	X	X
Lithic		X				X
Sombric			X	X	X	X
Torric			X	X	X	X
Ustic	X	X	X	X	X	X

Torrox

These are the Oxisols of arid climates. They are generally too dry for rainfed agriculture. Under present-day soil moisture regimes, weathering and soil formation is not expected to be intensive and, consequently, Torrox are believed to be relict soils. There are insufficient studies on the genesis of such soils to arrive at any conclusions about their origin.

The few that have been described in Hawaii, Kenya, and Somalia are all derived from basic or ultrabasic rocks. Their extent in the world has not been established. In Hawaii, Kenya, and Somalia, their soil temperature regime is isohyperthermic. Despite the aridic soil moisture regime, these soils are brought together with the Oxisols as it is believed that even if the moisture status is corrected through irrigation, the oxic properties still remain as limiting for most uses.

Definition

Torrox are the Oxisols that

1. Have a torric soil moisture regime.
2. Are never saturated with water or have chroma as follows:
    a. If there are no mottles, the chroma is 3 or more immediately below any epipedon that has a color value, moist, of 3.5 or less;
    b. If there are mottles below the dark epipedon, the chroma is more than 2 or the hue is redder than 2.5.
3. Do not have akric soil materials within 1.5 m of the soil surface.
4. Do not have a mollic or umbric epipedon.

Key to great groups of Torrox

CCA Torrox that have within 1.25 m of the mineral soil surface a petroferric contact or a lithoplinthic horizon or a subhorizon of at least 25 cm thick that was 20 percent or more by volume of petroplinthic gravel.

Paletorrox

CCB Other Torrox that have a hue of 2.5 or redder in all subhorizons of the oxic horizon to a depth of 1.5 m or more from the mineral soil surface.

Rhodotorrox

CCC Other Torrox that have a weighted average clay content in the upper 30 cm of the soil surface of more than 35 percent and the oxic horizon meets the clay increase requirement of an argillic horizon.

Kurotorrox

CCD Other Torrox.

Haplotorrox

Great groups in Torrox

Subgroups	Paletorrox	Rhodotorrox	Kurotorrox	Haplotorrox
Akric	X	X	X	X
Aquic	X	X	X	X
Eutric	X	X	X	X
Nithic		X	X	X

Humox

The Humox are Oxisols rich in organic matter. Most of them occur in the relatively cool, humid climates at high altitudes or at relatively high latitudes. The soils have an amollic or umbric epipedon underlain immediately by an oxic horizon. There are many low-elevation Oxisols that meet either the color or the organic-carbon requirement for the mollic or umbric epipedon, but not both, and so are not considered as Humox.

The high organic-matter status of the surface horizons makes the Humox potentially better soils of the Oxisols. If the epipedon is mollic, the base saturation of the surface horizons is high, making the soil even more favorable for agriculture.

Definition

Humox are the Oxisols that

1. Have a mollic or umbric epipedon.
2. Are never saturated with water or have chromas in the oxic horizon as follows:
    a. If there are no mottles, immediately below the epipedon that has moist color value of less than 3.5 there is dominant chroma of 2 or more.
    b. If there are distinct or prominent mottles within 50 cm of the soil surface, the dominant chroma is more than 3 or the hue is redder than 2.5.
3. Do not have akric soil materials within 1.5 m of the soil surface.

Key to great groups of Humox

CDA Humox that have a sombric horizon.

Sombrihumox

CDB Other Humox that have within 1.25 m of the mineral soil surface sheets that contain 30 percent or more gibbsite or a subhorizon that has 20 percent or more by volume gravel-size aggregates that contain 30 percent or more gibbsite.

Gibbsihumox

CDC Other Humox that have within 1.25 m of the mineral soil surface, a petroferric contact or a lithoplinthic horizon or a subhorizon of at least 25 cm thick that has 20 percent or more by volume of petroplinthic gravel.

Palehumox

CDD Other Humox that have a weighted-average clay content in the upper 30 cm of the soil surface of more than 35 percent and the oxic horizon meets the clay increase requirements of an argillic horizon.

Kurohumox

CDE Other Humox that have a hue of 2.5YR or redder in all subhorizons of the oxic horizon to a depth of 1.25 m or more from the mineral soil surface.

Rhodohumox

CDF Other Humox that have a mollic epipedon.

Eutrohumox

CDG Other Humox.

Haplohumox

Great groups in Humox

Subgroups	Sombrihumox	Gibbsihumox	Palehumox	Kurohumox	Rhodohumox	Eutrohumox	Haplohumox
Akric	X	X	X	X	X	X	X
Andic	X	X	X	X	X	X	X
Aquic	X	X	X	X	X	X	X
Batholithic				X		X	X
Epiaquic						X	X
Eutric	X			X	X		
Lithic				X		X	X
Plinthic			X	X		X	X
Nithic			X	X	X	X	X
Sombric		X	X	X	X	X	X

Ustox

Key to great groups of Ustox

CEA Ustox that have a sombric horizon.

Sombriustox

CEB Other Ustox that have within 1.25 m of the mineral soil surface sheets that contain 30 percent or more gibbsite or a subhorizon that has 20 percent or more by volume gravel-size aggregates that contain 30 percent or more gibbsite.

Gibbsiustox

CEC Other Ustox that have within 1.25 m of the mineral soil surface a petroferic contact or a lithoplinthic horizon or a subhorizon of at least 25 cm thick that has 20 percent or more by volume of petroplinthic gravel.

Paleustox

CED Other Ustox that have a weighted average clay content in the upper 30 cm of the soil surface of more than 35 percent and the oxic horizon meets the clay increase requirements of an argillic horizon.

Kurustox

CEE Other Ustox that have a hue of 2.5YR or redder in all subhorizons of the oxic horizon to a depth of 1.25 m or more from the mineral soil surface.

Rhodustox

CEF Other Ustox that have less than 35 percent clay or less than 12 percent of 15-bar water in all parts of the oxic horizon within 1.25 m of the mineral soil surface.

Psammustox

CEG Other Ustox.

Haplustox

Great groups in Ustox

Subgroups	Sombriorthox	Gibbsiorthox	Paleustox	Kurorthox	Rhodorthox	Psammorthox	Haplorthox
Akric	X	X	X	X	X	X	X
Andic	X			X			X
Aquic			X	X		X	X
Batholithic		X	X				X
Eutric	X		X	X	X	X	X
Lithic		X				X	X
Plinthic		X	X	X		X	X
Nithic			X	X	X		X
Sombric			X	X	X		X

Orthox

Key to great groups of Orthox

CFA Orthox that have a sombric horizon.

Sombriorthox

CFB Other Orthox that have within 1.25 m of the mineral soil surface sheets that contain 30 percent or more gibbsite or a subhorizon that has 20 percent or more by volume gravel-size aggregates that contain 30 percent or more gibbsite.

Gibbsiorthox

CFC Other Orthox that have within 1.25 m of the mineral soil surface a petroferric contact or a lithoplinthic horizon or a subhorizon of at least 25 cm thick that has 20 percent or more by volume of petroplinthic gravel.

Paleorthox

CFD Other Orthox that have a weighted-average clay content in the upper 30 cm of the soil surface of more than 35 percent and the oxic horizon meets the clay increase requirements of an argillic horizon.

Kurorthox

CFE Other Orthox that have a base saturation of 50 percent or more by NH_4OAc in the major part of the oxic horizon within 1.25 m of the mineral soil surface.

Eutrorthox

CFF Other Orthox that have a hue of 2.5YR or redder in all subhorizons of the oxic horizon to a depth of 1.25 m or more from the mineral soil surface.

Rhodorthox

CFG Other Orthox that have less than 35 percent clay or less than 12 percent of 15-bar water in all parts of the oxic horizon within 1.25 m of the mineral soil surface.

Psammorthox

CFH Other Orthox.

Haplorthox

Distinction between the Typic Haplorthox and other subgroups

1. Do not have (a) mottles that have chroma of 2 or less accompanied by red or dark mottles within 1.25 m of the soil surface, or (b) more than 5 percent, by volume, plinthite in all subhorizons within 1.25 m of the soil surface.
2. Do not have a layer in the upper 50 cm of the soil surface that has a texture finer than loamy fine sand, that is as much as 18 cm thick that has a bulk density (at $^1/_3$-bar water tension) of 0.95 g per cc or less in the fine earth fraction, that has a pH in 1*N* NaF of the fine earth fraction of 9.4 or more, and has a ratio of measured clay to 15-bar water of 1.25 or less.
3. Do not have a sombric horizon within 2 m of the soil surface.
4. Have a hue redder than 10YR in all parts of the upper 75 cm that have a color value moist of 4 or more, if there are mottles in high chroma within that depth and the hue becomes redder with depth by more than 2.5 Munsell units within the upper 1.5 m.
5. Have an oxic horizon that extends to a depth of 1.25 m or more below the mineral soil surface.
6. Do not have a lithic or paralithic contact (a) within 50 cm or (b) within 1.25 m of the mineral soil surface.
7. Do not have a subhorizon within 75 cm of the mineral soil surface that has an ECEC of less than 2.5 meq per 100 g clay.
8. Have less than 1 percent organic carbon in all subhorizons of the oxic horizon.
9. Do not have within 1.25 m of the soil surface pressure faces that are shiny with a few surfaces striated, or faces that show a metallic sheen.

Akric Haplorthox are like the Typic Haplorthox except for 7.
Andic Haplorthox are like the Typic Haplorthox except for 2.
Aquic Haplorthox are like the Typic Haplorthox except for 1 (a) without 1 (b).
Batholithic Haplorthox are like the Typic Haplorthox except for 6 (b).
Epiaquic Haplorthox are like the Typic Haplorthox except for 4.
Humic Haplorthox are like the Typic Haplorthox except for 8.
Leptic Haplorthox are like the Typic Haplorthox except for 5.
Lithic Haplorthox are like the Typic Haplorthox except for 6 (a) with or without 7 or 8.
Plinthic Haplorthox are like the Typic Haplorthox except for 1 (b) and 1 (a).
Nithic Haplorthox are like the Typic Haplorthox except for 9.
Sombric Haplorthox are like the Typic Haplorthox except for 3.

Great groups in Orthox

Subgroups	Sombriorthox	Gibbsiorthox	Paleorthox	Kurorthox	Eutrorothox	Rhodorthox	Psammorthox	Haplorthox
Akric	X	X	X	X		X	X	X
Andic	X			X	X		X	X
Aquic	X	X	X	X	X	X	X	X
Batholithic		X			X			X
Epiaquic			X		X		X	X
Humic	X	X	X	X	X	X	X	X
Leptic				X			X	X
Lithic		X			X			X
Plinthic			X	X	X			X
Nithic			X	X	X	X		X
Sombric			X	X	X	X	X	X

Interview of Guy D. Smith by Hari Eswaran, December 4, 1980

Question 1

As an historical introduction, when did the concept of Oxisols emerge? Was it probably the outcome of the earlier Latosols, and what were the compelling reasons for the big change in concepts?

Answer

The concept of Oxisols emerged rather gradually in the earlier approximation. At one time, we separated the soils in the highest category according to whether or not they had any horizons, they had a horizon that was very distinct, they had an A horizon and a B horizon, or currently a cambic horizon, or they had a B horizon of accumulation of clay or of amorphous materials. In the 6th Approximation, we adopted the concepts of the diagnostic horizons rather than the A, B, C horizons. The very strongly weathered soil horizons that we have in Oxisols were recognized as a special kind of B horizon, using the concept of the Latosols of Dr. Kellogg. This concept was very similar to that of the present concept of the oxic horizon. There was no big change in concepts; there was only a change in the application of the concepts. The soils with high variable charges, developed from pyroclastic materials in Hawaii, were called Latosols. The only general common feature of soils that were called Latosols that I could discover seemed to be that they occurred in intertropical regions. Nearly everything was called a Latosol in the soil survey of Hawaii. These included the present Andepts or proposed Andisols as well as Oxisols and Ultisols. At the time that we were working on the development of the 7th Approximation, we had virtually no data on the chemical properties of the soils of Hawaii other than their total analyses. The first concept we had of the Oxisols, then, was a mixture of what we now call Oxisols and Andepts.

It took some years to straighten out these differences. We recognized early that we needed an order for a kind of soil such as the Nipe of Puerto Rico, soils that consisted of completely weathered materials. The Nipe would be a good example, I think, of Dr. Kellogg's concept of a Latosol, although his concept was broader than that. He included soils such as Nipe along with soils that have distinct argillic horizons. The original definition was in descriptive terms, not in quantitative terms. Dr. Kellogg spoke of low activity of the clay, but did not specify what that was, and what is low to one person may be high to another; it depends on their experience and training. In developing Soil Taxonomy, it was recognized early that definitions could not be uniformly interpreted if they were written in qualitative terms rather than in quantitative terms. Qualitatively what is high and what is low in any property depends entirely on the experience of the individual who is trying to classify a particular soil, and it was our goal that the definitions would be such that competent pedologists, using the same information, would arrive at the same classification of the soil.

Question 2

Laterites were prominent criteria in the early approximations. With successive approximations, they nearly faded into oblivion. Today, some kinds of laterites are considered in some subgroups. Can you discuss this evolution and give your personal feelings.

Answer

Laterite is a name that has been used for more than 100 years. Over the many years, the word took on a wide variety of meanings, according to the individual who used it. Laterites included what we now call plinthite, a sesquioxide sheet, and an acric horizon, and the literature about laterites is extremely confusing. As a consequence, we decided not to use the term in the later approximations and we introduced the terms plinthite and sesquioxidic sheets in the 5th Approximation as substitutes. The first definition of plinthite included the domains in the soil that would harden on repeated wetting and drying and exposure, and the hardened relicts of that material. Subsequently, the term was restricted to the material that had not yet hardened irreversibly. As present, the plinthite name has been used as a formative element in two additional kinds of material: one the nodular, hard ironstone, which has been called petroplinthite. This usually is a transported material and occurs in the soil as stone lines. The other proposal for using

plinthite as a formative element is for lithoplinthite, which is a material that has hardened irreversibly in place, with a tubular structure that permits it to transmit water and permits roots to penetrate through it. Plinthite has been used as an interconnected matrix, or forms more than half of the matrix of some of the subgroups, in which it is present in smaller amounts than in the Plinthic great groups. The desirability of retaining the Plinthic great groups has been receiving considerable discussion in the international committee on Ultisols and Alfisols that have clays of low activity. At this time it is impossible to predict what recommendations the committee will make on the use of plinthite in the classification. The Plinthic great groups were established because we had little information about them in the United States, and the importance of laterite had been stressed so much in the literature. The Plinthic subgroups were recognized in the United State because they are brittle when moist, slowly permeable to water, and nearly impermeable to roots. They behave much as does a fragipan. Plinthic great groups in intertropical regions apparently do not have this particular property, and there is no question in my mind but that some changes in Soil Taxonomy will be required to reflect these differences.

Question 3

In the humid tropics, particularly in the nonaquic soils, it is extremely difficult to differentiate an oxic horizon from a cambic. The only criterion that separates the two is "traces of weatherable minerals." The Picacho series of Puerto Rico, Dystropept, has more gibbsite and a lower charge than the Matanzas, a Tropeptic Haplorthox. The Picacho is an Inceptisol because it has some feldspars. Is this potential to supply nutrient elements so critical as to separate the soils at order level? Do you see the need for special kinds of cambic horizons for the tropics?

Answer

In considering the importance of a critical limit between orders, we must always keep in mind that soils form a continuum, that there are intergrades between most kinds of soils that may go through other orders. In order to have a clearcut definition that defines the limits of a taxon, whether it is an order or a subgroup, we have to put the limit at a point which will divide the soils on either side of that point into different taxa. Thus two soils that are very similar, one on each side of that limit, are separated. They are more like each other than they are like the other soils in the taxon. The gradational change from one soil to another is reflected in names. The Picacho is an Oxic Dystropept and the Matanzas is a Tropeptic Haplorthox, indicating that these are gradational between the two orders. If one were to change the limit of the percentage of feldspars, it would only shift the subgroups nomenclature to another series, and would not eliminate any problem whatever. I do not at the moment foresee the need for special kinds of cambic horizons in intertropical soils.

Question 4

Wet oxic horizons are frequently mistaken for cambic horizons, primarily because of a color difference with the "C" and an apparent better structure. This may be one explanation for the lack of Aquox descriptions. Do you see this as a real problem, and how can we rectify it?

Answer

I think, perhaps, the principal reason for the lack of Aquox descriptions is the small area that they occupy in the world. The Aquox that I have seen have normally been small polypedons, a matter of a few hectares at most, and they are generally far apart in the landscape. They do exist, and a lack of description probably reflects the fact that their area is extremely small compared to the areas of the other kinds of Oxisols. I think that one would not have much trouble in identification of the Aquox if one finds a wet soil surrounded by other kinds of Oxisols. Its position in the landscape should be enough to guide the pedologist in classification, even in the absence of any laboratory data.

Question 5

The definition of Oxisols has created problems, especially with people from LDC's who go by the letter, as they frequently are not aware of the intent. The first problem is the classical question "Where

does an argillic horizon end and an oxic horizon begin, or vice versa?" I like to take the classical situation in Malaysia. The pedon has an A1 horizon of about 10 cm, a B1 horizon, which meets all the requirements of an oxic horizon, and this is underlain by B21t, B22t, etc. We happily called this pedon a Tropeptic Haplorthox until, during a recent workshop, some experienced pedologist classified it as a Typic Paleudult. The soil also shows the clay increase for the argillic horizon with clay skins in the major part of the B. The "Kandi" concept of ICOMLAC will not solve this problem.

Answer

We have two precedents in Soil Taxonomy for handling this particular question, where the transition horizon overlies the argillic horizon, and has all the characteristics of an oxic horizon. The first precedent is that of the cambic horizon, which by definition may not overlie an argillic horizon, unless it is separated from it by an albic horizon. The other precedent is where we have a spodic horizon that overlies an argillic horizon. In this case, the argillic horizon is not transitional, and the order is determined by the overlying surficial horizon, on the assumption that this horizon represents best the present processes going on in the soil. In dealing with the horizon that has the properties of an oxic horizon, but rests on an argillic horizon, it is possible to use either of these precedents. The limit of 30 cm thickness, mentioned under question 7, was set without thought that this would be a transitional horizon. In the discussion of ICOMLAC, I proposed that this limit be increased to 50 cm on the grounds that if it is that thick, the soil would behave more like an Oxisol than an Ultisol. In this situation, then, one could establish an udic subgroup of Oxisols, to separate soils with this horizon sequence, rather than at the order level.

Question 6

The Torrox present a conceptual problem that needs your remarks. Conceptually, Aridisols are soils with aridic moisture regimes and with a diagnostic subsurface horizon. If they are recent soils with no diagnostic subsurface horizons, they go into Entisols—Torriorthents and so on. But if they have an oxic horizon and an aridic moisture regime, they go into Oxisols. Why not Oxids instead of Torrox? If they have andic soil materials and an aridic soil moisture regime, they cannot go into the new Andisols, but instead go into Aridisols. Do we have a conceptual hiatus?

Answer

It would be possible to put the soils that have an oxic horizon and aridic soil moisture regime into either Oxisols or Ardisols. They were put into Oxisols rather than Aridisols on the assumpution that, if irrigated, they would behave more like Oxisols than like any other Aridisol. They do differ enormously in their properties from the vast bulk of the Aridisols.

Question 7

The Humox were created to separate the mountain or high level or low latitude Oxisol. Use of a temperature criterion at the suborder level has been criticized due to a duplication at the family level. As the definition of the Humox also requires that these soils have a low base saturation, it excludes high-elevation, organic-rich, base-rich soils and so defeats the objective of the suborder. Comments? The latter soils are present in Rwanda.

Answer

The use of temperature as a diagnostic at a high category level is duplicated at the family level and at the suborder level. The intent was to provide for broad temperature groups to be used for small-scale maps at the suborder level, and the much more refined temperature classes used at the family level are intended for use in making large-scale maps. It was assumed that an Oxisol, being strongly weathered in a cool, humid climate, would always have a low base saturation. The soils referred to in Rwanda were unknown to us at that time, and I have not yet seen the data on these soils. It seems difficult to imagine that in such an environment, a soil as highly weathered as an Oxisol would have retained its bases against leaching. With the evidence that such soils do exist, the definition of Humox will need to be reexamined. It was our general principle in the development of Soil Taxonomy to provide for soils that were known to exist, but not necessarily to provide for all possible kinds of soil that might or might not exist.

Question 8

An Ultic Haplorthox is frequently misclassified as an Oxic Tropudult. People ignore the sentence (page 329, Soil Taxonomy) "An appreciable increase in the percentage of clay with depth is a property shared with Ultisols, and defines the Ultic subgroup (in Haplorthox etc.)." The subgroup and the explantory sentence emphasize the fact that the clay increase by itself is insufficient to identify an argillic horizon. If the subsurface horizon has oxic properties, it is an oxic horizon and so will be keyed out as an Oxisol. Indirectly it implies that the oxic horizon has priority over the argillic horizon. Is this the intent?

Answer

It was the intent that the oxic horizon have priority over the argillic horizon [italics ours]. In fact, on page 20 of Soil Taxonomy, we stated "The argillic horizon by itself has little importance to soil classification. It is the accesory properties that are important." The soils that have a finer textured subsurface horizon appear to be giving considerable trouble in the field. The pedologists seem to be unable to agree generally as to whether or not this subsurface horizon is an argillic horizon. The problem has received much discussion from ICOMLAC and it is quite likely that some changes in the definition of the Oxisol will be needed and will be proposed by ICOMOX.

Question 9

Some Gibbsiorthox also have acric properties, and from a management point of view, the latter is a more limiting factor. It appears desirable to key the Acrorthox earlier and provide Gibbsic subgroups. Any particular reason why the present key was preferred?

Answer

Only two series of Gibbsiorthox have been recognized to date in Hawaii. None have been recognized in Puerto Rico. They are known, however, to occur in other islands in the South Pacific. Both of the series of Gibbsiorthox also have multiple sheets of gibbsite with root mats above the gibbsite sheets. These sheets behave as do the thin iron pans called placic horizons and other kinds of pans, although we have not defined them as a pan. This is, perhaps, the principle reason why the Gibbsiorthox were not included with the Acrorthox, which do not have these pans.

Circular Letter No. 8, November 1981

With the new responsibilities as head of SMSS, Eswaran relinquished the chairmanship of ICOMOX and Buol assumed the obligation to continue the circular letters and carry ICOMOX to completion.

In Circular Letter No. 8, the results of the Rwanda meeting were assembled for further deliberation by the total Committee. The major concern of the group naturally focused on the definitions of the oxic horizon and the order Oxisols. Since ICOMLAC (Moorman 1985) had now firmed up the kandic horizon and its use in Ultisols and Alfisols, ICOMOX was in a position to better define Oxisols. The following changes from the oxic horizon and classification key statements of Circular Letter No. 7 were presented in Circular Letter No. 8.

Rwanda Workshop Changes

Summary of Oxic Horizon Properties

In summary, the Oxic horizon is a subsurface horizon that:

1. Is at least 30 cm thick. [Reduced from 50 cm.]
2. Has a fine earth fraction (less than 2 mm) that has an apparent ECEC (NH_4OAc) bases plus 1*N* KCl-extractable Al/percent clay) less than 12 meq per 100 g clay or has an apparent CEC 7 (NH_4OAc CEC/percent clay) of less than 16 meq/100 g clay, whichever is lower. [Note the *or* between the two CEC methods, which was in keeping with the kandi criteria at that time but later to be changed to *and* as it was in ICOMOX Circular Letter No. 7.]
3. Has a pH value in 1*N* NaF (1:50) of less than 9.4. [This was to provide a boundary with andic soil materials but was later altered.]
4. Does not have as much as 10 percent weatherable minerals in the 50-200 micron faction. [Included to match the siliceous family and Quartzsipsamment limit both of which abut the Oxisols in nature, and to remove the often arbitary "trace of weatherable minerals" used in Soil Taxonomy.]
5. Has a texture of sandy loam or finer in the fine earth fraction and has more than 8 percent clay. [This removed the narrow range of soils that existed between the 15 percent clay content required in Soil Taxonomy and the sandy loam-loamy sand limit of Quartzipsamments. It also increased the usability of the coarse-loamy family. The 8 percent clay limit was later removed as unneeded.]
6. Has a diffuse upper textural boundary (i.e., less than 1.2x clay increase within a vertical distance of 12 cm). [Written to conform with the kandi horizon but later changed to 15 cm as the kandi horizon definition was changed to fit the limit established on the horizon boundary definition of gradual.]
7. Has less than 5 percent by volume that shows rock structure unless the lithorelicts containing weatherable minerals are coated with sesquioxides.
8. No soil material with more than 85 percent gravel, by volume, is considered an oxic horizon.

Key to Oxisols Order

Using the above definition of an oxic horizon, the following definition was presented as a proposal to be tested in the Key to Soil Orders (p. 92 in Soil Taxonomy).

Key Statement C. Other soils that either:

1. Have less than 40 percent clay in the upper 18 cm, after mixing; have an oxic horizon with an upper boundary within 1 m of the soil surface; and is not overlain by an argillic or kandic horizon, *or*
2. Have 40 percent or more clay (less than 2 micron) in the upper 18 cm of the soil, after mixing the top 18 cm, and have either an oxic or kandic horizon with an apparent CEC of the clay less than or equal to 16 meq/100 g clay (NH_4OAc, pH 7 method), the upper boundary of which is within 1 m of the soil surface.

This proposed statement differed from that in Circular letter No. 7 by altering the surface particle size that permitted the kandic horizon in Oxisols from 35 to 40 percent clay, a suggestion made by Guy Smith at the Thailand meeting. Also, akric soil materials, being within the range of the oxic horizon definition, were deleted as a diagnostic horizon and the concept was left to be defined in the great group keys. This eliminated the necessity of naming both oxic and akric in the order key. The upper boundary was placed at 1 m rather than 1.25 m.

Key to Suborders

Although not much discussion had taken place concerning the lower categories, a key to suborders was presented to correct an error in that category in Circular Letter No. 7 where Torrox was omitted. It was as follows:

CA Oxisols that are either saturated with water at some time during the year or are artifically drained and have one or both of the following characteristics associated with wetness:

a. A histic epipedon, or
b. If free of mottles, immediately below any epipedon that has moist color value of less than 3.5 there is a dominant chroma of 2 or less; or if there are distinct or prominent mottles within 50 cm of the soil surface, the dominant chroma is 2 or less, or the hue is 2.5Y or yellower.

Aquox

CB Other Oxisols that have akric soil materials within 1.5 m of the mineral soil surface.

Akrox

CC Other Oxisols that have a torric soil moisture regime.

Torrox

CD Other Oxisols that have a mollic or umbric epidedon.

Humox

CE Other Oxisols that have an ustic soil moisture regime.

Ustox

CF Other Oxisols.

Orthox

Circular Letter No. 9, March 1982

It was apparent that despite the effort in Circular Letter No. 7 to expand the discussion to all categories in Soil Taxonomy, most of the discussion at the Rwanda workshop centered on the oxic horizon and order criteria. While addressing the comments received about these items, Circular Letter No. 9 encouraged the Committee to begin testing specific pedons through all the categories in the system. Here are the comments on the oxic horizon and Oxisol order key from Circular Letter No. 9, as well as some rather drastic revisions of the suborder and great group categories that were proposed in an attempt to have the Committee consider them.

Comments on the Oxic Horizon Definition since Circular Letter No. 8

Many excellent editorial comments were received and incorporated. However, some points of fundamental difference arise that have profound consequences on the actual classification of Oxisols.

CEC Limits

Some committee members feel very strongly that the organic matter (o.m.) should be removed before an apparent CEC (CEC/percent clay) limit is set on the oxic horizon. This could also be done by assuming a CEC value (260 meq/100 g o.m. at pH 7 is suggested) of the organic matter and subtracting 2.6 meq/1 percent organic matter or 4.5 meq/1 percent organic carbon before calculating the apparent CEC. Some suggest that CEC criteria be waived where organic-matter contents are greater than a certain percentage.

The suggestion was made in Circular Letter No. 8 that this correction not be made, thus permitting some pedons with a higher CEC in the subsoil (because of organic contents) to probably classify as Inceptisols.

The rationale for the two points of view appear to summarize as follows:

1. Rationale to remove the o.m.:
   a. Soils with higher o.m. contents in the subsoil routinely occur in the natural Oxisol environment and should be classified as Oxisols.
   b. The original intent of the oxic horizon was to identify the weathering stage of the mineral part of the soil.
2. Rationale to leave the o.m. in the CEC value:
   a. CEC of the complete soil material is the criterion more related to soil property than CEC of the mineral component of the soil alone.
   b. CEC of o.m. has a high pH dependency, like the 1:1 clays, and is not easily destroyed in the B horizon.

c. For use or interpretation statements about the soil, such as low cation retention, possible cation leaching, etc., the charge characteristics of the soil with higher CEC, even in subsoil horizons, make these soils more closely related to non-Oxisols (Inceptisols in most cases) than to Oxisols.
d. More of the existing data is usable if an organic-matter correction is not used, and of course future analyses are somewhat simplified.

In attempting to visualize how this point may affect the placement of some pedons, I would speculate that if the oxic horizon were defined without o.m. removal, some pedons would end up as Oxic subgroups of Inceptisols with siliceous or kaolinitic families depending upon texture. If the o.m. is removed to affect the pedons' placement in the Oxisol order, it may be desirable to recognize them as subgroups or great groups with higher than "Ortho" or "Haplo" CEC/100 g clay or higher than modal o.m. content *in the oxic horizon.*

Either way it is necessary that we establish a class limit to serve as the basis for our consideration of Oxisol suborder, great groups, and subgroups. So, please share your opinions, and data, with me so I can put forth a working definition as soon as possible.

Weatherable Mineral Content of Oxic Horizons

There were no serious objections to setting the weatherable mineral content at "less than 10 percent in the 50-200 micron fraction." Ray Isbell makes the good point that it may be best to use the international standard of 20-200 microns or the USDA range from 50-250 microns. If one is to use grain counts, both are possible, but the optical microscope requirements are greater if one goes to 20 microns. There are variations between size fractions, but our usual practice in the U.S. is to count the most abundant fraction, either very fine sand (50-100 microns) or fine sand (100-250 microns).

At this time, I suggest that we state the 50-250 micron size fraction in the oxic horizon definition.

Adrien Herbillon makes a very interesting and I believe potentially useful suggestion. Adrien points out that total elemental data exists on many pedons. Since one of the objectives of the oxic horizon is to identify soil materials with very low potential sources of plant nutrients (K, Ca, Mg) there could be much existing data that would relate to the weatherable mineral class limit of 10 percent as determined by grain count. He then did something about it.

First, he prepared Table 1 to show oxide and elemental equivalents for some of the common minerals if present as 10 percent of the soil (weight basis). He then applied this reasoning to 33 pedons. As a possible limit to be tested he proposes that we look for a class limit for the oxic horizon to be between 25 and 40 meq/100 g soil when Ca^{++}, Mg^{++}, K^{+}, and Na^{+} are summarized. He states "the lower figure corresponds roughly to 10 percent muscovite and the higher figure to 2-3 percent hornblende." He suggests that to be "purists" we would want to subtract the exchangeable forms of these elements. (This may or may not be significant; it needs testing but requires more data.)

In the pedons he tested were 14 from Param's (Paramananthan 1977) Malaysia data. Of the Oxisols, only one Eutrorthox contained over 30 meq/100 g soil nutrient elements. He also plotted data from Cameroon and the Central African Republic.

Table 1. If the soil material contains 10 percent of the mineral named, it will contain the following percentage of oxide or element.

	Oxide (percent)				Element (meq/100 g soil)				
Mineral	CaO	MgO	K_2O	Na_2O	Ca^{++}	Mg^{++}	K^{+}	Na^{+}	Sum
Muscovite*			1.25				27		27
Orthoclase*			1.69				36		36
Anorthite*	2.01				72				72
Albite*				1.18				38	38
Enstatite*		4.0				200			200
Hornblende**	1.1	1.1	0.1	0.1	39	55	2	5	91
Biotite**		1.0	1.0			50	21		71
Mean									76

* End members.
** Mean values.
[Source: Adrien Herbillon, Circ. Letter No. 9, 1982.]

Of course, this limit does not separate Ultisols and Alfisols from Oxisols because "Pale" Ultisols also have less than 10 percent weatherable minerals, and Adrien found such soils from Nigeria to contain less than 10 meq bases/100 g soil.

Note: Adrien used whole soil (less than 2 mm) data, which is probably the most common in older analysis.

This approach may be useful to use in the situation presented by Ray Isbell from Indonesia (see ICOMOX Circular Letter No. 8).

Calculate your favorite data and send for the next letter.

Other Oxic Horizon Comments

Because of controversy among mineralogists, it is proposed we drop illite in our terminology. I presume we use mica or clay-sized mica. Comments?

I still feel rather uncomfortable with the rock fragment and lithorelict terms. Can anyone help make these more specific by providing operational criteria for identification?

Comments on the Oxisol Order

Almost all the comments received concerned the depth to the oxic horizon. There is support to require that the upper boundary of the oxic horizon be within 50 cm of the surface rather than within 1 m of the surface. I note that as a result of our discussions we moved it up from 1.25 m, as per Circular Letter No. 7, and of course we are up from the 2 m of Soil Taxonomy. It is probable that at whatever depth we set there will be areas in the world where it separates soils that should logically be kept together from the standpoint of local mapping. Almost everyone seems to agree that we not allow a kandic or an argillic horizon to overlie the oxic horizon if the surface 18 cm has less than 40 percent clay. There is one suggestion to waive this exclusion if the CEC characteristics within 1 m reach the low levels defined as "acric." (Comments?)

The areas of greatest concern would seem to be volcanic ash blankets. For your consideration and comment, let me suggest we also exclude soils from Oxisols that have a layer of more than 50 cm of material overlying the oxic or kandic horizon, if that material has a NaF pH value greater than 9.4.

Would 50 cm of "andic" material (0-50 cm depth) be picked up in Andisols (ICOMAND)?

One of our goals should be to bring the Oxisol order to a level as comparable as possible to the other orders. This presents very special problems. The most severe in my opinion is the limited number of detailed, quantitatively defined taxonomic series of the scale used in 1: less than 25,000 mapping. In my opinion, this lack of series results in the creation of too many taxa in the top categories.

To provide credence to our work we should attempt to document at least one pedon from each subgroup proposed. This may not be possible, but I believe we would be on a more solid basis if we physically documented as many pedons as possible and added to the number of higher categories with time rather than providing a large number of high categories only to find we had very few soils in many of them.

For the purpose of initiating discussion, I would like to propose, without presenting a detailed key at this time, a more limited number of higher category taxa than proposed in Circular Letter No. 7. I will attempt to cite some reasons for deleting existing or proposed higher taxa and rely on you to provide data and arguments to retain a given suborder or great group. I shall entitle the following the Oxisol KISS [keep it simple, stupid] proposal.

Key to Suborders (propose to use only moisture regimes)

Aquox (criteria as per Circular Letter No. 8)
Torrox (other Oxisols w/torric soil moisture regimes)
Ustox (other Oxisols w/ustic soil moisture regimes)
Orthox (other Oxisols)

Note: This deletes the Humox and Akrox from Circular Letters No. 7 and 8. It is argued that the moisture regimes provide more mappable, small-scale units, except in the Aquox. Aquox are retained because of precedence in other orders. The humox criteria of a mollic or umbric epipedon is distinctive but

is better recognized as a subgroup criterion when needed. The Akrox criterion is valid but best left to great group criteria on an equal basis with Eutro and Dystro (as in the Green Book, Soil Survey Staff 1975). Separate "Akr" great groups from "Eutro" and "Hapl" because CEC is too low.

Key to Great Groups

Aquox

1. Gibbsiaquox (per Circular Letter No. 7)
2. Akraquox (picks up Akrox of Circular Letter No. 7 that are wet)
3. Plinthaquox (per Circular Letter No. 8)
4. Humaquox (with umbric, mollic, or histic epipedon)
5. Haplaquox (others)

Note: deletes Paleaquox of Circular Letter No. 7; propose to handle as Petroferric subgroups.

Torrox

1. Akritorrox (Torris Akrox from Circular Letter No. 7 if found)
2. Kurotorrox (per Circular Letter No. 7 w/modification if found)
3. Eutrotorrox (more than 50 percent base-saturated at pH 7)
4. Haplotorrox (other Torrox)

Note: deletes Paletorrox of Circular Letter No. 7; propose to handle as Petroferric subgroups. Deletes Rodotorrox of Circular Letter No. 7; pick up as Rhodic subgroup. Adds Akritorrox if found. Adds Eutrotorrox if found.

Ustox

1. Gibbsustox (as per Circular Letter No. 7)
2. Akrustox (picks up Ustic Akrox from Circular Letter No. 7)
3. Kurustox (per Circular Letter No. 7 w/modification)
4. Eutrustox (per Soil Taxonomy)
5. Haplustox (other Oxisols)

Note: Deletes Sombriustox; proposed to treat as an extragrading subgroup. Deletes Paleustox; proposed to handle as Petroferric subgroups. Deletes Rhodustox; handle as Rhodic subgroups. Deletes Psammustox; handle as family criteria and perhaps less than 18 percent clay control section as Psammentic or Quartzipsammentic subgroups. Adds Eutrustox, as in Soil Taxonomy and Inceptisols. Adds Akrustox.

Orthox

1. Gibbsiorthox (per Circular Letter No. 7)
2. Akrorthox (picks up Typic Akrox of Circular Letter No. 7)
3. Kurorthox (per Circular Letter No. 7, w/modification)
4. Eutrothox (per Circular Letter No. 7 and Green Book)
5. Haplorthox (other Orthox)

Note: Deletes Sombriorthox; handle as an extragrading subgroup. Deletes Paleorthox; handle as Petroferric subgroups. Deletes Rhodorthox; handle as Rhodic subgroups. Deletes Psammorthox; handle as family to 18 percent; less than 18 percent clay as Psammentic intergrade subgroup.

Rationale

I need to explain some of the rationale for this approach.

a. The "Pale" indicates old, which it may be, but the morphologic feature is a hard contact. Preference is given to morphology rather than a pedogenic concept of age.
b. The sombric horizon feature probably occurs only in Oxisols and can be thought of as a unique feature. It seems to fit the concept of intergrading to no other named soil, i.e. extragrade Table 11, p. 90 of Soil Taxonomy.

c. Rhod has been used both as a great group and subgroup name in other orders. It seems less important to accessory characteristics than are Eutro, Ark, etc.
d. The Psam criterion indicates sandy, but it seems logical, and in line with other orders, to keep it for the near intergrades to Psamments. By using 18 percent clay in the control section, we fit with the coarse-loamy to fine-loamy family criteria.
e. The Kur criteria would be modified from Circular Letter No. 7 to include those Oxisols (Ustox and Orthox) that have greater than 40 percent clay in the surface horizon *and* are underlain by a clay-content increase sufficient to meet the kandi horizon definition.
f. The sequence in which the great groups are presented may need to be changed after discussion.
g. I have reservations about the Gibbsi great groups. This could be considered for family criteria. Please relate your experience or opinion.

If I add correctly, this proposes 4 suborders and 19 great groups versus 6 suborders and 37 great groups of Circular Letter No. 7. Presently in Taxonomy there are 18 great groups plus one implied in Torrox. So, perhaps, we are going the wrong way. I trust that you will test data in the systems rather than only argue the rationale. I understand that Guy Smith said he refrained from writing much about the rationale of the system so people would test the system rather than argue about the rationale.

Circular Letter No. 10, January 1983

From the reactions to Circular Letter No. 9 a 1983 ICOMOX Approximation of the oxic horizon definition and a 1983 ICOMOX Working Key were assembled. Committee members were asked to specifically test their existing pedon data according to the key.

Oxic Horizon Criteria (1983 ICOMOX Approximation)

CEC Limits

Use oxic horizon CEC limits of less than 12 meq/100 g clay using NH_4OAc (ammonium acetate) extracted bases plus 1*N* KCl-extractable Al^{+++}/percent clay or less than 16 meq/100 g clay by the NH_4OAc, pH 7 method (CEC 7 soil/percent clay). In other words, continue to use apparent CEC of the clay without o.m. removal or consideration of silt and sand CEC as in Soil Taxonomy, but substitute NH_4OAc bases plus KCl-Al less than 12 meq/100 g clay for NH_4Cl less than 10 meq/100 g clay in Soil Taxonomy.

Weatherable Mineral Content of the Oxic Horizon

Weatherable mineral contents in oxic horizons are defined as less than 10 percent of the 50-250 micron fraction if that size fraction constitutes at least 20 percent of the soil material less than 2 mm in diameter. For soils with less than 20percent fine sand and very fine sand (50-250 microns), the oxic horizon contains less than 40 meq of K + Mg + Ca + Na/100 g soil on a total elemental analysis basis after coated gravel removal.

This limit increases the amount of weatherables allowed slightly, but brings it in line with other limits — i.e., "pale" and siliceous family limits. The total elemental limit in very clayey oxic horizons seems justified from the Adrien Herbillon study and hopefully will avoid the problem Ray Isbell found in Indonesia.

Oxic Horizon Texture

The oxic horizon is coarse-loamy (sandy loam) or finer and contains 8 percent or more clay.

This lowers the limit from 15 percent clay to the midrange of the sandy/loamy family limit. It is a fine point, but essentially says that if the less than 2 mm material, finer than sand (less than 50 micron), contains more than 50 percent clay, it is an oxic horizon. High clay/silt ratios are characteristic of Oxisols.

Other Oxic Horizon Features

Oxic horizons are at least 30 cm thick; however, thinner horizons of oxic compositions may be recognized in taxonomic unit definitions.

No more than 85 percent gravel or coarser particles are included in the oxic horizon.

The upper boundary of the oxic horizon is diffuse with respect to clay content increase (i.e., less than 1.2x clay content increase with a vertical distance of 12 cm).

The pH value of an oxic horizon in 1*N* NaF (1:50) is less than 9.4.

Less than 5 percent of the oxic horizon volume has rock structure, unless the rocks containing weatherable minerals are coated with sesquioxides. Such sesquioxide-coated material of gravel size or coarser should be removed prior to the total elemental analysis specified in the weatherable mineral content section.

Key to Oxisols (1983 ICOMOX Working Key)

(Page references are to Soil Taxonomy.)

Key Statement C (p. 92).

Other Soils that either:

1. Have less than 40 percent clay in the upper 18 cm, after mixing, and an oxic horizon with its upper boundary within 1 m of the soil surface and not overlain by an argillic or a kandic horizon, *or*
2. Have 40 percent or more clay in the upper 18 cm of the soil, after mixing, and either an oxic horizon *or* a kandic horizon with an apparent CEC of the clay fraction less than or equal to 16 meq/100 g clay (NH_4OAc, pH 7 method), the upper boundary of which is within 1 m of the soil surface.

Oxisols

Key to Suborders (1983 ICOMOX Working Key) (p. 323)

CA Oxisols that are either saturated with water within 30 cm of the mineral surface for at least 30 days per year in most years or are artifically drained and have one or both of the following characteristics associated with wetness.

a. A histic epipedon, and/or
b. If free from mottles immediately below any epipedon that has a moist color value of less than 3.5 there is a dominant chroma of 2 or less; *or*, if there are distinct or prominent mottles within 50 cm of the soil surface, the dominant chroma is 3 or less or the hue is 2.5Y or yellower.

Aquox

CB Oxisols that have an aridic (torric) soil moisture regime.

Torrox

CC Other Oxisols that have a ustic soil moisture regime.

Ustox

CD Other Oxisols.

Orthox

Key to Great Groups

Key to Aquox great groups (1983 ICOMOX Working Key)

CAA Aquox that have within 1.25 m of the mineral soil surface sheets containing 30 percent or more gibbsite or a subhorizon that has 20 percent or more by volume, gravel-sized aggregates that contain 30 percent or more gibbsite.

Gibbsiaquox

CAB Other Aquox that have 35 percent or more clay in the oxic horizon and an apparent effective cation-exchange capacity [(NH_4OAc bases + KCl aluminum)/percent clay] of less than 1.5 meq/100 g clay in the oxic horizon and within 2 m of the soil surface.

Akraquox

CAC Other Aquox that have plinthite forming a continuous phase within 1.25 m of the soil surface.
Plinthaquox

CAD Other Aquox that have an umbric, mollic, or histic epipedon.
Umbraquox

CAE Other Aquox.
Ochraquox

Key to Torrox great groups (1983 ICOMOX Working Key)

CBA Torrox that have an apparent effective cation-exchange capacity of less than 1.5 meq/100 g clay in the oxic horizon within 2 m of the soil surface.
Akritorrox

CBB Other Torrox that are more than 35 percent base saturated (pH 7) in all parts to a depth of 1.25 m.
Eutrotorrox

CBC Other Torrox.
Haplotorrox

Key to Ustox great groups (1983 ICOMOX Working Key)

CCA Ustox that have within 1.25 m of the mineral surface sheets that contain 30 percent or more gibbsite or a subhorizon that has 20 percent or more by volume gravel-size aggregates that contain 30 percent or more gibbsite.
Gibbsiustox

CCB Other Ustox that have an apparent effective cation-exchange capacity of less than 1.5 meq/100 g clay in the oxic horizon within 2 m of the soil surface.
Akrustox

CCC Other Ustox that are more than 35 percent base saturated (NH_4OAc) in all parts to a depth of 1.25 m.
Eutrustox

CCD Other Ustox that have more than 40 percent clay in the surface 18 cm after mixing, and a clay content increase with depth of more than 1.2x within a thickness of 30 cm (i.e., kandic horizon).
Kurustox

CCE Other Ustox.
Haplustox

Key to Orthox great groups (1983 ICOMOX Working Key)

CDA Orthox that have within 1.25 m of the mineral surface sheets that contain 30 percent or more gibbsite or a subhorizon that has 20 percent or more by volume gravel-size aggregates that contain 30 percent or more gibbsite.
Gibbsiorthox

CDB Other Orthox that have an apparent effective cation-exchange capacity of less than 1.5 meq/100 g clay in the oxic horizon within 2 m of the soil surface.
Akrorthox

CDC Other Orthox that are more than 35 percent base saturated (NH_4OAc) in all parts to a depth of 1.25 m.
Eutrorthox

CDD Other Orthox that have more than 40 percent clay in the surface 18 cm, after mixing, and a clay content increase with depth of more than 1.2x within a thickness of 30 cm (i.e., kandic horizon).
Kurorthox

CDE Other Orthox.
Haplorthox

Proposed Subgroup Distinctions

In the following sections I have attempted to write the Typic subgroup definition as done in Soil Taxonomy. I have attempted to name all the implied subgroups in Appendix 1 in this letter. This is where we need to have specific examples. It is my opinion that we will need to demonstrate through examples that there are too many or too contrasting subgroups within a great group before we can justify additional great groups.

Aquox (proposed subgroup distinctions)

Typic Gibbsiaquox are defined as Gibbsiaquox that:

a. Have apparent effective CEC values per 100 g clay less than 1.5 meq in the oxic horizon above 2 m.
b. Have a mollic, umbric, or histic epipedon.
c. Do not have continuous-phase plinthite within 1.25 m of the soil surface.

Typic Akraquox are defined as Akraquox that:

a. Have a mollic, umbric, or histic epipedon.
b. Do not have continuous-phase plinthite within 1.25 m of the soil surface.

Typic Plinthaquox are defined as Plinthaquox that:

a. Have a mollic, umbric, or histic epipedon.

Typic Umbraquox are defined as Umbraquox that:

a. Have color chromas of 2 or less in all horizons below the epipedon.
b. Do not have as much as 5 percent plinthite in any horizon to a depth of 1.25 m.
c. Have less than 35 percent base saturation in some part above 1.25 m.

Typic Ochraquox are defined as Ochraquox that:

a. Have color chromas of 2 or less in all horizons below the epipedon.
b. Do not have as much as 5 percent plinthite in any horizon to a depth of 1.25 m.
c. Have less than 35 percent base saturation in some part above 1.25 m.

Torrox (proposed subgroup distinctions)

Typic Akritorrox are defined as Akritorrox that:

a. Do not have lithic or petroferric contact within 1.25 m of the soil surface.
b. Have an ochric epipedon.

Typic Eutrotorrox are defined as Eutrotorrox that:

a. Do not have lithic or petroferric contact within 1.25 m of the soil surface.
b. Have an ochric epipedon.

Typic Haplotorrox are defined as Haplotorrox that:

a. Do not have lithic or petroferric contact within 1.25 m of the soil surface.
b. Have an ochric epipedon.

Ustox (proposed subgroup distinctions)

Typic Gibbsiustox are defined as Gibbsiustox that:

a. Have an apparent effective CEC/100 g clay less than 1.5 meq in the oxic horizon above 2 m.
b. Have no mottles of 2 or less chroma within 1.25 m of the soil surface.

Typic Akrustox are defined as Akrustox that:

a. Do not have lithic or petroferric contact within 1.25 m of the soil surface.
b. Have no mottles of 2 or less chroma within 1.25 m of the soil surface.
c. Have less than 5 percent plinthite in all horizons to a depth of 1.25 m below the soil surface.

Typic Eutrustox are defined as Eutrustox that:

a. Do not have lithic or petroferric contact within 1.25 m of the soil surface.
b. Have no mottles of 2 or less chroma within 1.25 m of the soil surface.
c. Have less than 5 percent plinthite in all horizons to a depth of 1.25 m below the soil surface.
d. Have an ochric epipedon.
e. Have 5YR or yellower color hues in all parts of the oxic horizon above 1.25 m below the soil surface.
f. Have less than 40 percent clay in the surface 18 cm after mixing.

Typic Kurustox are defined as Kurustox that:

a. Do not have lithic or petroferric contact within 1.25 m of the soil surface.
b. Have no mottles of 2 or less chroma within 1.25 m of the soil surface.
c. Have less than 5 percent plinthite in all horizons to a depth of 1.25 m below the soil surface.
d. Have an ochric epipedon.
e. Have 5YR or yellower color hues in all parts of the oxic horizon above 1.25 m below the soil surface.

Typic Haplustox are defined as Haplustox that:

a. Do not have lithic or petroferric contact within 1.25 m of the soil surface.
b. Have no mottles of 2 or less chroma within 1.25 m of the soil surface.
c. Have less than 5 percent plinthite in all horizons to a depth of 1.25 m below the soil surface.
d. Have an ochric epipedon.
e. Have 5YR or yellower color hues in all parts of the oxic horizon above 1.25 m below the soil surface.

Orthox (proposed subgroup distinctions)

Typic Gibbsiorthox are defined as Gibbsiorthox that:

a. Have an apparent effective CEC/100 g clay less than 1.5 meq in the oxic horizon above 2 m.
b. Have no mottles of 2 or less chroma within 1.25 m of the soil surface.

Typic Akrorthox are defined as Akrorthox that:

a. Do not have lithic or petroferric contact within 1.25 m of the soil surface.
b. Have no mottles of 2 or less chroma within 1.25 m of the soil surface.
c. Have less than 5 percent plinthite in all horizons to a depth of 1.25 m below the soil surface.
d. Have a udic soil moisture regime.

Typic Eutrorthox are defined as Eutrothox that:

a. Do not have lithic or petroferric contact within 1.25 m of the soil surface.
b. Have no mottles of 2 or less chroma within 1.25 m of the soil surface.
c. Have less than 5 percent plinthite in all horizons to a depth of 1.25 m below the soil surface.
d. Have a udic soil moisture regime.
e. Have an ochric epipedon.
f. Have 5YR or yellower color hues in all parts of the oxic horizon above 1.25 m below the soil surface.
g. Have less than 40 percent clay in the surface 18 cm after mixing.

Typic Kurorthox are defined as Kurorthox that:

a. Do not have lithic or petroferric contact within 1.25 m of the soil surface.
b. Have no mottles of 2 or less chroma within 1.25 m of the soil surface.
c. Have less than 5 percent plinthite in all horizons to a depth of 1.25 m below the soil surface.
d. Have a udic soil moisture regime.
e. Have an ochric epipedon.
f. Have 5YR or yellower color hues in all parts of the oxic horizon above 1.25 m below the soil surface.

Typic Haplorthox are defined as Haplorthox that:

a. Do not have lithic or petroferric contact within 1.25 m of the soil surface.
b. Have no mottles of 2 or less chroma within 1.25 m of the soil surface.
c. Have less than 5 percent plinthite in all horizons to a depth of 1.25 m below the soil surface.
d. Have a udic soil moisture regime.
e. Have an ochric epipedon.
f. Have 5YR or yellower color hues in all parts of the oxic horizon above 1.25 m below the soil surface.

Oxisol Families

Particle-Size Classes (Ref. p. 386)

In Oxisols the clayey particle sizes have not been further separated into fine and very fine. I believe the history of this decision rested on the low CEC of the clay and concern that a little more clay made only a slight difference in CEC. After looking at the P-adsorption isotherms and our work in Bolivia and Brazil, it is my opinion that we would be including useful information to use the fine (35-59 percent) clay and very fine (less than or equal to 60 percent clay) families. I expressed this to the American Society of Agronomy meetings last month and received no adverse reactions. I would like your opinions.

Mineral Classes (Ref. p. 387)

Most Oxisols, if fine or very fine texture, will be kaolinitic mineralogy and if fine-loamy or coarse-loamy will be siliceous mineralogy. It seems to me that gibbsitic is taken care of by the "Gibbsi" great groups. Is Ferritic of any importance to anything?

Our work with P adsorption has shown that both iron and clay content have a positive correlation to P adsorption; thus, when used as a ratio as in oxidic families, the result is meaningless. We in the Ultisols of the southeastern U.S. stopped using it several years ago. I believe we should recommend deletion of the oxidic family. Comments?

Calcareous and Reaction Classes

At present I see no use for these classes in the Oxisols.

Soil Temperature Classes

Oxisol classification is primarily but not entirely in the iso-temperature groups. Because the crops grown are different in iso-modified regimes, it is my opinion the limits should be altered. This issue is being considered by another "ICOM," but if any of the ICOMOX committee wish to suggest criteria, I will forward the suggestions.

Soil Depth Classes; Soil Slope Classes; Soil Consistence Classes; Classes of Coatings; Classes of Cracks

All these classes seem to be of little importance in Oxisol families, with the possible exception of depth and slope classes. If each of you will give pages 383 to 389 some thought and write me, I'll summarize in the next circular letter.

Unless we find some more meaningful mineralogical families, we may consider not using mineralogy as a family criterion in Oxisols where siliceous and kaolinitic are almost redundant to the order definition. What are your opinions?

One possible mineral family would reflect HIV (hydroxy Al interlayered) as a significant component of the clay because of its potential to supply Al^{+++}.

Testing the Criteria

As was discussed in Circular Letter No. 9, we have a uniquely difficult task in ICOMOX because so few Oxisols are represented in the detailed mapping and classification of U.S. soils at the series level. In order to have confidence in any structure we may propose to classify Oxisols, we will need to accumulate experience with representative pedons and in so doing document the need for further modification.

Appendix 1.
Oxisols (1983 Working Key, Summary)

Suborders	Great Groups	Implied Subgroups (+ Typic)
Aquox	Gibbsiaquox	a) Hypric; b) Ochreptic; c) Plinthic
	Akraquox	a) Ochreptic; b) Plinthic
	Plinthaquox	a) Ochreptic
	Umbraquox	a) Aeric; b) Plinthic; c) Eutric
	Ochraquox	a) Aeric; b) Plinthic; c) Eutric
Torrox	Akritorrox	a) Lithic or Petroferric; b) Humic
	Eutrotorrox	a) Lithic or Petroferric; b) Humic
	Haplotorrox	a) Lithic or Petroferric; b) Humic
Ustox	Gibbsiustox	a) Hypric; b) Aquic
	Akrustox	a) Lithic or Petroferric; b) Aquic; c) Plinthic
	Eutrustox	a) Lithic or Petroferric; b) Aquic; c) Plinthic; d) Humic; e) Rhodic; f) Kuric
	Kurustox	a) Lithic or Petroferric; b) Aquic; c) Plinthic; d) Humic; e) Rhodic
	Haplustox	a) Lithic or Petroferric; b) Aquic; c) Plinthic; d) Humic; e) Rhodic
Orthox	Gibbsiorthox	a) Hypric; b) Aquic
	Akrorthox	a) Lithic or Petroferric; b) Aquic; c) Plinthic; d) Perudic
	Eutrorthox	a) Lithic or Petroferric; b) Aquic; c) Plinthic; d) Perudic; e) Humic; f) Rhodic; g) Kuric
	Kurorthox	a) Lithic or Petroferric; b) Aquic; c) Plinthic; d) Perudic; e) Humic; f) Rhodic
	Haplorthox	a) Lithic or Petroferric; b) Aquic; c) Plinthic; d) Perudic; e) Humic; f) Rhodic

Circular Letter No. 11, August 1983

Data from 8 pedons were selected from among the data received and reproduced in Circular Letter No. 11, with comment, as to how each fit into the 1983 ICOMOX Working Key. By this time, the Working Key had been written in BASIC for the Apple II personal computer. An example of how the program worked was distributed for the Pariquera pedon, which classified as a Typic Haplorthox; fine, kaolinitic, hyperthermic.

The testing of specific data into a complete key, order through family, created a flurry of comments and opinions. These comments were summarized as follows for the committee to react to.

Summary of Comments on Circular Letter No. 10

Lab Accuracy

A number of people are concerned, as we should be, by the variation present in many of our analyses. Of particular concern are clay percentage and the apparent effective cation-exchange capacity (ECEC) of 1.5 meq/100 g clay criteria in the Akrorthox. I would very much like to have an answer to this very real problem, but quite candidly there does not seem to be an answer except to do our best assuming the *appropriate* techniques are correctly followed in all laboratories. It is tempting to suggest substituting alternative procedures, such as 15-bar water times X, for percent clay, but until such techniques are subject to the same interlaboratory checking as other techniques have been, it does not seem prudent to require such tecnhiques in the taxonomic criteria. The other side of the issue is that by requiring "new" or innovative techniques in the Soil Taxonomy criteria, laboratories will be "forced" to improve their techniques. I welcome comments on the subject.

KCl-Al

One specific technique problem concerns the KCl extract and whether it is titrated so that the result should be called Al plus H or analyzed on an atomic absorption unit for Al. Our present criterion states KCl-extractable Al, and John Kimble is going to look into how much error may be introduced if the titratable H is included. Others of you may have experience with this problem.

Oxic Horizon Texture

Decreasing the Soil Taxonomy required clay content from 15 percent to the sandy loam (sandy/loamy family) limit with an absolute 8 percent clay minimum has been discussed and a suggestion made to consider the more sandy Oxisols as "Psammentic" subgroups. This suggestion is in line with the Soil

Taxonomy "Quartzipsammentic Haplorthox," defined as having a texture coarser than sandy clay loam in all parts of the oxic horizon above 1.25 m. Comments?

Oxisols

The key to Oxisols in ICOMOX 1983 creates at least two points of concern caused by the second part of criterion no. 2. Specifically, concerns relate to the kandic horizon option. The first was an oversight not to hold the kandic horizon, as used in the Oxisol order, to the same weatherable mineral and rock structure limits as the oxic horizon. Secondly, it is probably a good move to incude an equal to or less than 12 meq/100 g clay apparent ECEC in the kandic horizon requirement as used in Oxisols.

Key statement C (Item 2) is proposed to be altered to the following:

> 2. . . . *or* a kandic horizon with an apparent CEC of the clay fraction equal to or less than 16 meq/100 g clay (NH_4OAc, pH 7 method) or equal to or less than 12 meq/100 g clay (bases + KCl-Al ECEC method), the upper boundary of which is within 1 m of the soil surface and conforming to the weatherable mineral, texture, thickness, pH, and rock structure requirement of the oxic horizon.

Does the above meet with your approval? It seems too long, so perhaps someone will help simplify.

Oliveira provided some examples of profiles meeting the ICOMOX 1983 criteria that are on river terraces and suggests exclusion of stratification, irregular distribution of carbon with depth, etc., or providing for Fluventic subgroups. Comments?

Oliveira also points out three profiles he feels are excluded from Oxisols because sand-sized concretions were counted in the sand fraction, making the quartz content less than 90 percent. Unless the concretions contained K, Mg, Ca, or Na, I think they should be counted as non-weatherable. Perhaps we need to clarify this in the oxic horizon definition by allowing the "less than 40 meq/100 g soil of Mg + Ca + K + Na" total elemental analysis to mineralogically qualify such soils.

The O.C. debate continues. Please note the high O.C. contents that still give apparent ECEC less than 12 meq in some of the enclosed data.

Aquox suborder

A question is raised about the Aquox definition. Guy [Smith] always said "water is the criterion of wetness." In deleting the continuous-phase plinthite option presently in Soil Taxonomy, the 1983 Working Key attempted to shorten but not alter the second option. As I read the ICOMOX 1983 Aquox key statement it could be rewritten as follows:

CA Oxisols that are either:

1) Saturated with water within 30 cm of the mineral surface for at least 30 days per year in most years (6 of 10 years), or
2) Artificially drained and have one or more of the following characteristics:
    a) A histic epipedon.
    b) No mottles and a moist color value of less than 3.5 and a dominant chroma of 2 or less, immediately below the epipedon.
    c) Distinct or prominent mottles within 50 cm of the soil surface and a dominant chroma of 3 or less and a hue of 2.5Y or yellower immediately below the epipedon.

Does the above clarify, confuse, or meet with your approval?

Humox suborder

The Humox still has its friends even though your chairman tried to move the concept to subgroups, as Humic subgroups, and make the presence of either an umbric or mollic epipedon the only criterion. Most of the questions were simply "what happened?" Well, I forgot to specifically call attention to the trial shift of O.C. criteria to the subgroup, leaving the suborder definitions as only soil moisture regime criteria. I need comments on this move now that you can see profile T320, for example. Schargel suggests great groups "Hum" in Ustox and Orthox using umbric and mollic criteria. Hari [Eswaran] says keep Humox as udic, with mollic or umbric and O.C. percent greater than 1 to 1 m.

Ustox suborder

Ray suggests the word Xeric be included in the criteria so that a few Ustox near Perth, Australia, a non-iso temperature regime, are put in the Ustox suborder. A Xerox suborder would be too small. Comments?

Akr great groups

The suggestion has been made to require that the less than 1.5 meq/100 g clay apparent ECEC be above 1 m rather than "in the oxic horizon above 2 m." My concern is that the O.C. content will cut out many "Akr" pedons if that is done (see profile Malanda). Ray Isbell suggests a great group limit of less than 1.5 meq/100 g soil, thereby eliminating the influence of percent clay errors and increasing the size of "Acr" great groups. Such a change would tend to collect coarser texture in the "Acr" great groups. Comments?

Kur great groups

Frank [Moorman] and Ray [Isbell] point out that the kandic horizon limit is 1.2x clay content within 12 cm, not 30 cm. The CCD and CDD statements should be changed to 12 cm instead of 30 cm.

Sombri great groups

Only Frank [Moorman] took note, without great remorse, of its absence. Do we all conclude that the present definition is unworkable and best left to series criteria in detailed surveys?

Gibbsi criterion

Two votes to delete from the great group and pick up at subgroup; another suggestion is to put at family level. If used, there are problems with size and number of "sheets." Sheets is a term not well defined in Soil Taxonomy. Comments?

Tropeptic subgroups

Some people miss "Tropeptic" and favor a 1.25 m depth to the bottom of the oxic horizon as a criterion rather than "discernible structure." See profile no. 1032 for a possible example. Comments with examples are needed. There is no doubt that the footnote on page 327 of Soil Taxonomy has been difficult to agree upon in the field with road cuts and pits of various degrees of drying.

Kuric subgroup

In response to a question on the rationale it is simply to identify soils with large surface area and thus high P sorption in the plow layer or potential plow layer. Kurustox and Kurorthox will have similar features but for agronomic interpretations the Eutro great groups need a way to identify this P-sorption potential characteristic. The family criteria alone would do this and perhaps "Kur" should be deleted from subgroups; perhaps even great groups?

Families

Strong support for fine (35-59 percent clay) and very fine families (equal to or greater than 60 percent clay) families to replace only the clayey family in Soil Taxonomy. Unless there are objections, not yet voiced, it appears that this will be one of the final ICOMOX recommendations.

Ferritic families

Perhaps 40 percent is too high a Fe_2O_3 limit; 30 percent is suggested as more useful in Brazil. Need examples.

Oxidic families

Igo Lepsch called my attention to the Soil Taxonomy requirement that these families have to have less than 90 percent quartz. He says this present criterion limits the family to basaltic areas where sand is ilmenite and magnetite. He feels the 90 percent quartz criterion should be excluded from clay-textured soils. This family has not been useful in Ultisols of the U.S. A zero point of charge above pH 5.2 in the oxic horizon above 2 m is suggested as a possible alternative criterion.

Gibbsitic families

This family is presently defined as whole soil gibbsite content greater than 40 percent. Several data show percent gibbsite content in the clay fraction but few data that I have determine it on a whole soil basis. Personal experience in the U.S. finds much gibbsite in the silt fraction of our Inceptisols. I need more data and comments on this point.

Further Pedon Tests

[Attached to the original letter were eight pedon data descriptions.] Note that I have put a subgroup name followed by (83) on each pedon. The (83) is to identify that the placement was by the 1983 ICOMOX Working Key. I need you to check out my placement and offer your comments.

Circular Letter No. 12, February 1984

This letter followed the ICOMAND workshop in Chile and Ecuador, affording an opportunity to bring the boundary of Oxisols and Andisols into better focus via the proposals they discussed. A review of the more controversial points was presented in Circular Letter No. 12. Also, the entire key was reproduced this time, entitled the 1984 ICOMOX Working Key. For the first time all the subgroup criteria were presented as direct questions about the pedon being classified rather than as comparisons with the Typic. The 1984 ICOMOX Working Key is reprinted here.

Definitions

Proposals for change and discussion.

Oxic Horizon Criteria (from p. 2-3, Circular Letter No. 10)

Richard Schargel points out that in item D, Other oxic horizon features, we placed a clay content increase of less than 1.2x within a vertical distance of 12 cm. That was done to correspond with the minimum thickness of a diffuse boundary (5 inches) in the Soil Survey Manual. Richard correctly called attention to the limit of 15 cm now used for the minimum limit of a diffuse boundary. I think it is desirable to keep such arbitrary limits consistent with field nomenclature whenever possible, so I propose we recognize 15 cm rather than 12 cm. This will need to be edited into agreement with the "Kandi" great groups of Ultisols and Alfisols as well as the "Kur" great groups of Oxisols.

Also in item D, the NaF pH value of an oxic horizon was placed at less than 9.4. This was done to provide a limit with the Andisols. Several have pointed out this value is too low and the ICOMAND group now favors the use of the following:

1) acid oxalate-extractable aluminum value less than 2 percent or a 4*M* KOH-extractable aluminum value less than 1.5 percent;
2) less than 85 percent phosphate retention;
3) $^1/_3$-bar bulk density of 0.9 g/cc or more to exclude material with andic soil properties.

During the ICOMAND meeting a few problems were encountered with their proposed limit as it related to coarser textured material, and I expect there will be some slight changes. It is my opinion that we should drop the 9.4 NaF pH value limit on the oxic horizon and accept limits that match those adopted by ICOMAND. Certainly there should not be any opportunity to either overlap or leave a gap between the oxic horizon and andic materials. In many cases CEC/100 g clay will make oxic material more exclusive than other non-andic material, but the inclusion of material bulk density, P retention, and active aluminum limits should reduce confusion.

Herbillon, who has contributed much data and comment to this discussion, suggests we simply state that "oxic and kandic materials do not have the assemblage of properties characteristic of andic soil material." We then allow ICOMAND to claim what they want for andic. Comments?

Oliveira expresses some concern about the lowering of the clay content. In one case it is thought that with low clay contents, slight amounts of CEC from organic sites and coarser particles may exclude some soils from Oxisols.

Lepsch suggests that we say "the oxic horizon has a texture finer than loamy sand with a silt (20-50 micron)/clay ratio less than 1." Does this cause anyone problems?

Key to the Order Oxisols (comments and concerns)

C Order (key to Oxisol Order)

There were some suggestions to shorten the statement, which I shall try to do.

Concern was expressed that fluventic situations where soil material of oxic horizon composition was stratified as in a recent floodplain should be excluded from Oxisols. A statement to the effect that the pedon should not have irregular distribution of organic carbon with depth is suggested as an addition to the key statement. Comments?

CA	Aquox	No comments since Circular Letter No. 11.
CB	Torrox	No comments since Circular Letter No. 11.
CC	Ustox	Some feel a Xerox suborder should be created even if very limited in extent. Australia, the only place reported to have such soils, proposes to put them in the Ustox suborder. Are there any other examples of Oxisols in a xeric soil moisture regime?
CD	Orthox	(Humox) Opinion seems evenly split as to the desirability of separating the Oxisols high in organic-matter content from other Oxisols at a suborder level. Questions include (1) Should such a suborder include both ustic and udic soil moisture regimes as in Soil Taxonomy or only udic soil moisture regimes? (2) Should 16 kg cm^2/m be used as the criterion or should the mollic or umbric epipedon be used? (3) Should separation be made at the subgroup level?

The following are some of the points made to support the various viewpoints.

1. There are large areas of Humox defined best as containing more than 12 kg cm^2/m in São Paulo, Brazil (i.e., define Humox suborder at 12 kg cm^2/m).
2. Using the umbric and mollic criteria fits well into the prominent A concept of the Brazilian classification (i.e., use only umbric and mollic to define subgroups, no Humox).
3. Does organic carbon content carry as many accessory characteristics as soil moisture regime? (The property that carries the most accessory characteristics should be used as the criterion in the highest categories. p. 8-11 in Taxonomy).

As you will see later, I have retained mollic and umbric as criteria at the subgroup level in this draft, but certainly the question needs further debate.

Great Group Criteria (comment and discussion)

Akr great groups received a great deal of comment. There seems to be considerable objection to Ray Isbell's proposal to base the ECEC value of less than 1.5 meq/100 g whole soil unless corrections were made for O.C., and there is considerable opposition to attempting to apply any correction for O.C. except to call for its destruction before analysis. That also creates problems. It is doubtful, although I have no specific data, that O.C., at the contents usually present at depth in soils considered to be *Akr*, would increase the ECEC values very much because the pH values are usually very low, albeit unbuffered.

Igo Lepsch offers an interesting suggestion that may satisfy some of the arguments about our ability to get reliable clay contents in such soils and thus cause severe error in ECEC/percent clay calculations. He suggests that we define *Akr* as less than 1.5 meq/100 g fines (fines equals material less than either 50 or 20 microns).

Oliveira suggests the criterion be within 1 m rather than the present 2 m, unless there is a mollic or umbric epipedon in which case 2 m should be used.

The requirement to have more than 35 percent clay in the oxic horizon of the Akraquox was questioned and appears to be a mistake on my part in preparing the ICOMOX 1983 Working Key, so unless someone knows otherwise, I will delete it.

Kur great groups seem to be agreeable to most, although there are concerns that eroded phases of Paleudults (Kandiudults) and Paleustults (Kandiustults) will now classify in the Oxisol order. I have not yet seen data that would substantiate this. There is also the desire to keep soils with strong angular and subangular blocky structure and profuse clay skins (approximately more than 5 percent of the cross sectional area in thin section) out of the Oxisol order. Examples *and* comments are needed.

Gibbsi great groups did not receive any further support and it appears that there is a general feeling for the criteria to be picked up at the family category. That is where I propose to put them in the 1984 draft.

Subgroups (comment and discussion)

Tropeptic subgroups, dropped in 1983, received an equal number of positive and negative comments. Most felt that the structure criterion was not adequate in the past, but there was mixed feeling as to whether a lower depth to an oxic horizon was appropriate. It was proposed that Tropeptic subgroups have either CEC, ECEC, or weatherable mineral values too high to qualify for an oxic horizon in some 10-cm horizon above 100 cm but below an oxic horizon. I have not included Tropeptic in the 1984 draft, but the point still needs debate.

The *Andic* subgroup is new one, indicating an intergrade to andic material in the Andisol order. The definition proposed by ICOMAND (Circular Letter No. 5, 1983) is: "Soils that have throughout a minimum thickness of more than 18 cm in the upper 75 cm, a bulk density less than l g/cc, and an acid oxalate-extractable aluminum value of more than 1.5 percent." I have included the Los Ulmos pedon from Chile for your consideration. It almost meets the criteria. I have included an Andic Kurorthox subgroup for testing.

Vitric subgroups are also proposed by ICOMAND. "Some 18 cm thickness, within the upper 75 cm, containing more than 60 percent by volume of volcaniclastics, cinders, pumice-like material in the fraction greater than or equal to 2 mm *or* more than 40 percent of the sand fraction is glass or glass coated *and* yielding acid-oxalate-extractable aluminum values of more than 0.4 percent," is the approximate definition of such a subgroup. Not having any examples, I have not included it in this draft. Do we have such Oxisol pedons?

Lepsch points out that the redder than 5YR hue in *Rhodic* subgroups indicates the presence of hematite as shown by several studies. I received several discussions of the subject and essentially all indicated a great deal of hesitation about the criteria. But there were essentially no firm recommendations for other criteria. As I have been looking at the descriptions of several profiles sent from Brazil, one practical problem comes to light, and that is the use of 4YR and 3.5YR hues.

It is my opinion that we all want to recognize color some place above series (see Pot Boiler section) but we all are aware that color is a continuum in Oxisols and any limit we make is arbitrary. Attempts to relate other properties to red-yellow colors have not been very successful except in local areas. My instinct is to set a simple limit in such situations, so for this draft we will keep the "redder than 5YR in some part above 1.25 m" as a subgroup criterion, but this discussion is certainly not closed. My guess is that Rhodic subgroups may be more common in Ustox than in Orthox because the dry season promotes hematite formation, so we may consider Xanthic, or some other yellow color, as subgroup criteria in Ustox with Typic being the redder ones.

Families

Fine and *very fine* seem to find favor with *everyone.*

Gibbsitic families may need to have the Taxonomy definition enlarged to include gravel-sized aggregates and sheets. I have no experience with what was in the *Gibbsi* great groups. There is a need for some examples. Comments?

Ferritic families at 30 percent Fe_2O_3 is supported, and the suggestion is made that perhaps two iron content families are needed. The limits of 18-40 percent Fe_2O_3 and greater than 40 percent Fe_2O_3 are being suggested in Brazil and may be useful in Oxisols. Further study is needed.

Reaction Families

There is a suggestion that in Oxisol great groups, other than *Eutr*, it could be useful to use reaction classes. Rather than acid/nonacid as is used, for example, in Aquepts, it is proposed that Allic be used in a soil (there is a need to propose a depth) more than 50 percent saturated with Al. I assume the procedure is KCl-Al/ECEC x 100, but that was not specified in the proposal. Comments?

Oxidic families were briefly discussed and two suggestions made to define them: (1) include more than 40 percent gibbsite plus Fe_2O_3 on a whole soil basis or (2) lower the proposed ZPNC to 5.0 in any part above 2 m or a positive delta pH in some part above 2 m. What is your reaction?

Projected Schedule

I hope to assemble a rather extensive number of pedons, tested in the 1984 ICOMOX (enclosed) in the next circular letter, which I plan for about July 1984. Plans have been submitted for an ICOMOX workshop in 1985, at which time we would try to complete a draft of Oxisols for formal worldwide testing.

As for the next 5 months, keep the pedon data coming, hopefully in a form ready to photocopy, but if not, I'll try to do better in assembling what you send. Also, in the absence of data, express your opinions. If I missed your comments in this letter, hit me with them again before June.

"Pot Boilers"

One of my colleagues uses this term to describe suggestions made to heat up a discussion.

One such suggestion was to use color as essentially the only great group criterion. Three colors were mentioned, a yellow (approximately 7.5YR or yellower), a red (approximately 5YR or redder with moist hues above 4), and a dark red (approximately 5YR or redder with moist values of 4 or less). What are your opinions?

Should perudic be used as a suborder criterion rather than as a subgroup? Logic would dictate that if soil moisture regime is the best criterion to carry accessory features, then perudic should be used at the suborder level. However, how do those of you who have perudic soil moisture regimes see such a suborder?

Should Lithic and Petroferric be separate subgroups in the Oxisols? Are there any Plinthic subgroups of Ustox or Orthox?

Should Ferritic and Gibbsitic be combined for a gibbsiferritic family for perhaps iron plus gibbsite greater than 40 percent?

What about a Ferrikaolinitic for kaolinite-dominated soils with, say, 18 to 40 percent from oxide?

1984 ICOMOX Working Key

The following is a trial format that I have found works best when writing Soil Taxonomy for use in a small computer. Note that about all that is different from Soil Taxonomy is the sentence structure, especially in the keys to subgroups. The sentences you read were typed from the computer program and represent what you see on the video screen when working with the program. I have also done this with the Ultisols, including all the U.S. series and most of the Inceptisols, including the U.S. series. I believe computer keying of Soil Taxonomy offers a rapid and accurate control of the system that has the potential to reduce expensive and tardy printing of approved changes in the system. Tell me what you think of the structure of the key as well as your response to the content of the key. [Attached to the original letter was Appendix I, an example for the Los Ulmos pedon in Chile.]

Order Key Statement C

(To key after Histisols, Spodosols, and the proposed Andisols) 1984 ICOMOX Working Key:
Other soils that either have:

1. An oxic horizon with its upper boundary within 1 m of the soil surface and is not overlain by an argillic or kandic horizon, or

2. 40 percent or more clay in the surface 18 cm, after mixing, and either an oxic horizon *or* a kandic horizon with an apparent CEC of the clay fraction less than 16 meq/100 g (NH_4OAc) or an apparent ECEC of the clay (bases plus KCl Al) equal to or less than 12 meq/100 g clay, with an upper boundary within 1 m of the soil surface and meeting the weatherable mineral and rock fragment requirement of an oxic horizon.

Key to Oxisol Suborders (1984 ICOMOX Working Key)

CA Is this Oxisol either saturated with water within 30 cm of the mineral surface 30 days per year in most years or artifically drained, and does it have either:
1) A histic epipedon, or
2) If not mottled, a moist color value less than 3.5 and a dominant chroma of 2 or less immediately below any epipedon, or
3) If there are distinct or prominent mottles within 50 cm of the surface, a dominant chroma of 3 or less or a hue of 2.5Y or yellower?

If yes Aquox

CB Does this Oxisol have an aridic soil moisture regime?

If yes Torrox

CC Does this Oxisol have an ustic or xeric soil moisture regime?

If yes Ustox

CD If no to all above:

Orthox

Aquox key

CAA Does this Aquox have an apparent ECEC of less than 1.5 meq/100 g clay in the oxic horizon and within 2 m of the surface?

If yes Akraquox

CAB Does this Aquox have plinthite forming a continuous phase within 1.25 m of the soil surface?

If yes Plinthaquox

CAC Does this Aquox have an umbric, mollic, or histic epipedon?

If yes Umbraquox

CAD If no to all above:

Ochraquox

Torrox key

CBA Does this Torrox have an apparent ECEC of less than 1.5 meq/100 g clay in the oxic horizon within 2 m of the soil surface?

If yes Akritorrox

CBB Is this Torrox more than 35 percent base saturated in all parts to a depth of 1.25 m?

If yes Eutrotorrox

CBC If no to all above:

Haplotorrox

Ustox key

CCA Does this Ustox have an apparent ECEC of less than 1.5 meq/100 g clay in the oxic horizon within 2 m of the soil surface?

If yes Akrustox

CCB Is this Ustox more than 35 percent base saturated (NH_4OAc) in all parts to a depth of 1.25 m?

If yes Eutrustox

CCC Does this Ustox have more than 40 percent clay in the surface 18 cm after mixing, and a clay content increase with depth of more than 8 percent, absolute, within a thickness of 15 cm occurring within 1.5 m of the surface?

If yes Kurustox

CCD If no to all above:

Haplustox

Orthox key

CDA Does this Orthox have an apparent ECEC of less than 1.5 meq/100 g clay in the oxic horizon within 2 m of the soil surface?

If yes Akrorthox

CDB Is this Orthox more than 35 percent base saturated (NH_4OAc) in all parts to a depth of 1.25 m?

If yes Eutrorthox

CDC Does this Orthox have more than 40 percent clay in the surface 18 cm, after mixing, and a clay content increase with depth of more than 8 percent, absolute, within a thickness of 15 cm occurring within 1.5 m of the surface?

If yes Kurorthox

CDD If no to all above:

Haplorthox

Great Group Keys

Akraquox:
Does this Akraquox have:
1) An ochric epipedon?
2) More than 5 percent plinthite in some layer within 1.25 m of the soil surface?
0) None of the above?
1 = Ochreptic Akraquox
2 = Plinthic Akraquox
0 = Typic Akraquox

Plinthaquox:
Does this Plinthaquox have:
1) An ochric epipedon?
0) None of the above?
1 = Ochreptic Plinthaquox
0 = Typic Plinthaquox

Umbraquox:
Does this Umbraquox have:
1) Chromas of more than 2 in the horizon immediately below the epipedon?
2) More than 5 percent plinthite in any horizon surface?
3) Base saturation more than 35 percent (NH_4OAc) in all parts above 1.25 m?
0) None of the above?
1 = Aeric Umbraquox
2 = Plinthic Umbraquox
3 = Eutric Umbraquox
0 = Typic Umbraquox

Ochraquox:
Does this Ochraquox have:
1) Chromas of more than 2 in the horizon immediately below the epipedon?
2) More than 5 percent plinthite in some horizon above 1.25 m?

3) Base saturation more than 35 percent (NH_4OAc) in all parts above 1.25 m?
0) None of the above?
1 = Aeric Ochraquox
2 = Plinthic Ochraquox
3 = Eutric Ochraquox
0 = Typic Ochraquox

Akritorrox:
Does this Akritorrox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) A mollic or umbric epipedon?
0) None of the above?
1 = Petroferric Akritorrox
2 = Lithic Akritorrox
3 = Humic Akritorrox
0 = Typic Akritorrox

Eutrotorrox:
Does this Eutrotorrox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) A mollic or umbric epipedon?
0) None of the above?
1 = Petroferric Eutrotorrox
2 = Lithic Eutrotorrox
3 = Humic Eutrotorrox
0 = Typic Eutrotorrox

Haplotorrox:
Does this Haplotorrox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) A mollic or umbric epipedon?
0) None of the above?
1 = Petroferric Haplotorrox
2 = Lithic Haplotorrox
3 = Humic Haplotorrox
0 = Typic Haplotorrox

Akrustox:
Does this Akrustox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) Mottles of 2 or less chroma within 1.25 m of the soil surface?
4) More than 5 percent plinthite in some horizon above 1.25 m?
0) None of the above?
1 = Petroferric Akrustox
2 = Lithic Akrustox
3 = Aquic Akrustox
4 = Plinthic Akrustox
0 = Typic Akrustox

Eutrustox:
Does this Eutrustox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) Mottles of 2 or less chroma within 1.25 m of the soil surface?
4) More than 5 percent plinthite in some horizon above 1.25 m?
5) A mollic or umbric epipedon?
6) Color hues redder than 5YR in some part of the oxic horizon above 1.25 m?
7) More than 40 percent clay in the surface 18 cm after mixing and the top of a kandic horizon within 1.5 m?
0) None of the above?
1 = Petroferric Eutrustox
2 = Lithic Eutrustox
3 = Aquic Eutrustox
4 = Plinthic Eutrustox
5 = Humic Eutrustox
6 = Rhodic Eutrustox
7 = Kuric Eutrustox
6 and 7 = Kuric Rhodic Eutrustox
0 = Typic Eutrustox

Kurustox:
Does this Kurustox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) Mottles of 2 or less chroma within 1.25 m of the soil surface?
4) More than 5 percent plinthite in some horizon above 1.25 m?
5) A mollic or umbric epipedon?
6) Color hues redder than 5YR in some part of the oxic horizon above 1.25 m?
0) None of the above?
1 = Petroferric Kurustox
2 = Lithic Kurustox
3 = Aquic Kurustox
4 = Plinthic Kurustox
5 = Humic Kurustox
5 and 6 = Humic Rhodic Kurustox
0 = Typic Kurustox

Haplustox:
Does this Haplustox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) Mottles of 2 or less chroma within 1.25 m of the soil surface?
4) More than 5 percent plinthite in some horizon above 1.25 m?
5) A mollic or umbric epipedon?
6) Color hues redder than 5YR in some part of the oxic horizon above 1.25 m?
0) None of the above?
1 = Petroferric Haplustox
2 = Lithic Haplustox
3 = Aquic Haplustox
4 = Plinthic Haplustox
5 = Humic Haplustox
6 = Rhodic Haplustox
0 = Typic Haplustox

Akrorthox:
Does this Akrorthox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) Mottles of 2 or less chroma within 1.25 m of the soil surface?
4) More than 5 percent plinthite in some horizon above 1.25 m?
5) A mollic or umbric epipedon?
0) None of the above?
1 = Petroferric Akrorthox
2 = Lithic Akrorthox
3 = Aquic Akrorthox
4 = Plinthic Akrorthox
5 = Humic Akrorthox
0 = Typic Akrorthox

Eutrorthox:
Does this Eutrorthox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) Mottles of 2 or less chroma within 1.25 m of the soil surface?
4) More than 5 percent plinthite in some horizon above 1.25 m?
5) A perudic soil moisture regime?
6) A mollic or umbric epipedon?
7) Color hues redder than 5YR in some part of the oxic horizon above 1.25 m?
8) More than 40 percent clay in the surface 18 cm after mixing and the top of a kandic horizon within 1.5 m depth?
0) None of the above?
1 = Petroferric Eutrorthox
2 = Lithic Eutrorthox
3 = Aquic Eutrorthox
4 = Plinthic Eutrorthox
5 = Humic Eutrorthox
6 = Rhodic Eutrorthox
7 = Kuric Eutrorthox
7 and 8 = Kuric Rhodic Eutrorthox
0 = Typic Eutrorthox

Kurorthox:
Does this Kurorthox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) Mottles of 2 or less chroma within 1.25 m of the soil surface?
4) More than 5 percent plinthite in some horizon above 1.25 m?
5) A perudic soil moisture regime?
6) A mollic or umbric epipedon?
7) Color hues redder than 5YR in some part of the kandic horizon above 1.25 m?
8) An 18 cm or thicker layer in the upper 75 cm with a bulk density less than 1 g/cc and acid oxalate content more than 1.5 percent?
0) None of the above?
1 = Petroferric Kurorthox
2 = Lithic Kurorthox
3 = Aquic Kurorthox
4 = Plinthic Kurorthox
5 = Perudic Kurorthox

6 = Humic Kurorthox
7 = Rhodic Kurorthox
8 = Andic Kurorthox
6 and 7 = Humic Rhodic Kurorthox
0 = Typic Kurorthox

Haplorthox:
Does this Haplorthox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) Mottles of 2 or less chroma within 1.25 m of the soil surface?
4) More than 5 percent plinthite in some horizon above 1.25 m?
5) A perudic soil moisture regime?
6) A mollic or umbric epipedon?
7) Color hues redder than 5YR in some part of the oxic horizon above 1.25 m?
0) None of the above?
1 = Petroferric Haplorthox
2 = Lithic Haplorthox
3 = Aquic Haplorthox
4 = Plinthic Haplorthox
5 = Perudic Haplorthox
6 = Humic Haplorthox
7 = Rhodic Haplorthox
5 and 6 = Humic Perudic Haplorthox
6 and 7 = Humic Rhodic Haplorthox
0 = Typic Haplorthox

Textural Family:
Weighted average of texture between 20 and 1 m or lithic or paralithic contact whichever is shallower.
1) Less than 18 percent clay.
2) 18 to 34.9 percent clay.
3) 35 to 59.9 percent clay.
4) 60 percent or more clay. (If more than 35 percent gravel or coarser material, add skeletal to name below.)
1 = coarse-loamy
2 = fine-loamy
3 = fine
4 = very fine

Mineralogical Family (same depth as Textural Family):
1) More than 40 percent iron oxide (28 percent Fe).
2) More than 40 percent aluminum oxide (including gravel).
3) A ZPNC above 5.2 above 1 m.
4) Less than 35 percent clay and none of the above.
5) More than 35 percent clay and more than 50 percent halloysite
6) More than 35 percent clay and more than 50 percent kaolinite.
0) None of the above.
1 = Ferritic
2 = Gibbsitic
3 = Oxidic
4 = Siliceous
5 = Halloysitic
6 = Kaolinitic
0 = Mixed

Circular Letter No. 13, July 1984

The order criteria were critically tested by four pedons sent in from Australia. The questions raised are outlined in Appendix I of this letter. The main part of the letter deals with questions of criteria definitions, with some new items, such as Udox, receiving attention. The items of discussion and Appendix I concerning the profiles that critically test the order criteria are reprinted from Circular Letter No. 13.

Discussion

Definitions (for oxic horizon, see Circular Letter No. 10)

Oxic-kandic

To provide mutual exclusive criteria between an oxic horizon and a kandic horizon, it was proposed that "the upper boundary of the oxic horizon is diffuse with respect to clay content increase (i.e., less than 1.2x clay content increase within a vertical distance of 12 cm)." Schargel suggested, ICOMOX Circular Letter No. 12, that the distance be 15 cm to correspond with the minimum thickness of a diffuse soil horizon boundary as defined in the new Soil Survey Manual. There seems to be no disagreement with this proposal, and the new limit has been included in the kandic proposal being readied for general circulation and testing by USDA-SCS, Washington, D.C.

Oxic-andic

The suggestion by Herbillon that "Oxic and kandic materials do not have the assemblage of properties characteristic of andic soil material" seems agreeable to everyone.

Clay content and O.C. removal in oxic horizon

These points were discussed by several people. Ray Isbell sees no problem with O.C. because of its low content at the depths where the oxic horizon can be considered. John Kimble points out that at the low pH values the CEC contribution of O.C. is very small and does not contribute to ECEC although it would via a CEC pH 7 method. CEC from non-clay sized particles would be of greater concern (Note: apparent CEC is calculated as CEC of whole soil x100/ percent clay), so any CEC in coarser minerals or O.C. *appears* to be in the clay. Wim Sombroek wants the O.C. out of there, but he supports the suggestion of Igo Lepsch to limit the oxic horizon to "textures finer than loamy fine sand with silt (20-50 micron)/clay ratios less than 1." Igo's suggestion in effect sets the lower limit of clay at 8 percent if you do a little arithmetic on the textural triangle and there is not too much silt in the 2-20 micron range. Wim suggests the ratio of 20-50 micron silt/clay ratio be lowered to 0.5 or even 0.25, thus keeping the percent clay even higher. My concern is that we not leave a small and potentially troublesome gap between Oxisols and Quartzipsamments, but still insist that some clay be present to reflect low CEC, "weathered"

conditions. If found, and I have no examples, a material that is not part argillic or spodic could have less than 15 percent clay and a silt/clay ratio above 1 (or 0.5 according to Wim's suggestion) and thus be forced into Inceptisols or Entisols. Now, in Soil Taxonomy, any such material less than 15 percent clay is excluded from Oxisols and the coarse-loamy family of Oxisols contains from 15 to 18 percent clay. I believe that is too narrow for a meaningful family.

In summary, I get the impression that there is general agreement to take coarser pedons into the Oxisol order, i.e., greater than 8 percent clay if the silt/clay ratio is small. I also believe that the ECEC argument, i.e., O.C. does not influence apparent CEC of the clay when CEC is done with an unbuffered salt, seems acceptable to most. I think the ECEC contribution from silt and sand would be rare in material with less than 10 percent weatherable minerals, but I have no hard data. Further data and discussion are welcomed.

Elemental composition-weatherable minerals

Ray Isbell says it is easier for him to get total elemental analysis than to determine weatherable mineral content. At present (see ICOMOX Circular Letter No. 10) we are suggesting less than 40 meq of bases, after removal of coated gravel, on soil material with less than 20 percent fine plus very fine sand. There has been little comment on this point, and I think Ray Isbell is asking if it is possible to use a minimum total elemental composition for any material considered as oxic. Comments? Since most total elemental analysis data are on a percent oxide basis, perhaps one of you good chemists would provide a quick and easy conversion to meq.

Key to Order (see Circular Letter No. 12)

Fluventic situations, i.e., irregular decrease of O.C. with depth, produced little comment and no disagreement. John [Kimble] and Wim [Sombroek] agree that sampling is too "tricky" for an order criterion. If other criteria qualify the pedon for Oxisols, the Fluventic features should not exclude it. I therefore conclude that we will not consider irregular decrease in O.C. content as a criterion at the order level.

Key to Suborders (see Circular Letter No. 12)

CA	Aquox:	Ray [Isbell] suggests a comma after years, i.e., . . . per year in most years, or artificially . . . . He asks if the 30 days have to be consecutive, and my opinion is no, just 30 days/year in most years (6 of 10). Comments?
CB	Torrox:	Everyone is happy!
CC	Ustox:	Everyone is happy!
CD	Orthox:	We have a troublemaker in our group. Pedro Sanchez questions the use of "Orth" as the formative element for Oxisols in udic and perudic soil moisture regimes. As he points out, there are probably more hectares of Ustox than Orthox and to the non-taxonomist "Orth," with its connotation of "the common ones," means little. He suggests that "Ud" (i.e., Udox) is a more appropriate suborder name. I find it rather difficult to argue against his suggestion. In other orders where soil moisture regime is used as a criterion for suborder, "Ud" is the formative element. Udoll, Udalf, Udult, and Udert. Comments?

More on the Humox Question

None of the letters I received since Circular Letter No. 12 favor the use of Humox. Most favor using the dark color and high organic content as subgroup criteria, as is presently proposed. Some have questioned combining umbric and mollic epipedons as criteria for Humic subgroups, and the reasoning I have used is the same as that used in Inceptisols and Ultisols. The primary concern is the application of lime, which can make an umbric epipedon into a mollic epipedon in one day.

John Kimble suggests using O.C. content as a criterion for "Hum" great groups in Ustox and Orthox (Udox). Careful consideration would have to be given to where in the sequence of the key to consider such soils. Comments?

Great Group Comments

Akr

Wim [Sombroek] made a good, but not helpful, response when he wrote "The Akr criteria remain problematic." Several letters addressed this problem and the suggestions were quite diverse relative to specific criteria. However, I think I can see some general trends coming together and I will attempt to formulate the concerns without being specific as to individual suggestions. If you feel I have overlooked your specific point of view, I will expect to hear from you before the next circular letter.

Depth to acric material has support for 1, 1.5, and 2 m. Since Akr is the first great group in each great group key, the deeper we look for criteria the more Akr soils we have. There is support for ECEC values from 1 to 2 meq/100 g soil and 100 g clay/100 g silt plus clay. There is a well-thought out suggestion to use the following combination of properties:

1) KCl pH equal to or greater than 4.8 and delta pH greater than –0.2
2) ECEC less than or equal to 2 meq/100 g silt plus clay
3) ECEC – AEC less than 1 meq/100 g silt plus clay
4) Exchangable Al in KCl less than ECEC/2 (in silt plus clay)

The objective of recognizing Akr great groups is to recognize those soils where the subsoil charge is so low that it is easily manipulated and cation movement is relatively rapid. In this regard and, for the purpose of discussion, I am going to suggest that Akr great groups be defined as having a 5 cm or greater layer within *1 m* of the surface with either:

1) an apparent ECEC less than or equal to 2 meq/100 g of silt plus clay (less than 50 micron) and
2) KCl-exchangeable Al less than 1.5 meq *or*:
3) KCl pH equal to or greater than 4.8 *and* delta pH greater than –0.2 (delta pH = KCl pH value – 1:1 H_2O pH value)

I'm certain I can expect to hear more on this subject.

Kur

There seems to be general agreement on the Kur great groups. I look on them as the Oxisol contribution to filling the gap between ideal Ultisols and ideal Oxisols. As such they really do not please most of us as good examples of either. But, there are a lot of them in the world. (See Appendix 1 [in this Letter] for a further problem in this area.)

Plinthaquox

Plinthaquox is questioned as a real soil. Does anyone have data that could substantiate this great group?

Other

I can find no correspondence related to the other great groups so I assume everyone is happy.

Subgroup Comments

Lithic and *Petroferric* both seem to be desired as subgroup names. No reconsideration was requested in any of the letters, although these subgroups are confined to Torrox in Australia.

Plinthic subgroups of Ustox and Orthox (Udox) are reported to exist. The identification of plinthic subgroups, in any order, is still a very qualitative process. Ray Daniels is with Ray Isbell at this time and they are working on the problem. I would like to say "solving" the problem, but from the letters I get I'm not very optimistic.

Perudic subgroups are not looked on with much favor in Australia. What about the Asian experience?

Humic subgroups in Torrox probably do not exist, as per the Australian experience. I will delete them from the key unless someone can find some.

Rhodic subgroups brought a "mixed bag" of responses. The one common thread in all responses is that everyone has a "feeling" color should be used, but the inability to quantitatively link color with other properties leaves us all a bit hesitant about using it as a high level in Soil Taxonomy. As most of you

know, except for Rhodic subgroups, the U.S. experience has resulted in leaving these red-yellow hue characteristics to series criteria, and I know of no attempts within the U.S. to upgrade the criteria although almost every family of Ultisols has series defined as redder than 5YR and series yellower than 5YR. Locally it appears important and, as John Kimble pointed out, 60 percent of our soils are separated by color, so it is not from a lack of trying that we seem unable to attribute "total soil properties" to soil color. As a couple of papers in the recent Soil Science Society of America Journal further illustrate (Curi and Franzmeier 1984, Kosmas et al. 1984), finer iron oxide particles, usually geothic and yellower in color, have greater reactivity with phosphate. But, when the iron content is allowed to range a few percentage points within a soil series, as usually happens say from 40 to 60 percent clay, the reactivity of the "total" soil is more related to clay content than is the reactivity of the iron oxide. In Soil Taxonomy we are urged to classify soil, not pieces of soil. This probably accounts for the historical treatment red and yellow Podzolics and Latosols have received, i.e., they became known as red yellow Podzolics, red yellow Latosols, etc. because experiences found there was no practical difference associated only with color.

Unless someone has a more specific suggestion, I believe we can let the present color criteria at the sugroup level remain as in Circular Letter No. 12 and reevaluate it after we get more experience with Oxisol series. Comments?

Everyone is not exactly in favor of *Humic* subgroups (see Humox discussion), but the grouping has its supporters and seems worth keeping as is until we test it further. If there are examples of Humic sugroup soils needing reclassification after a few years of normal cultivation, and free of excessive erosion, we need to have documentation. Several people mentioned this possibility but I have not seen the documentation.

Aquic and *Aeric* sugroups were not discussed. We need examples.

Possible New Subgroups

Tropeptic subgroups are on several people's minds, but, in general, these people prefer to stay away from the criterion used in Soil Taxonomy, i.e., structure. Some feel we may be getting at the same thing with the *Kur* great groups or, in the case of *Kuric* subgroups, with the *Eutro* great groups. Others suggest that we should try a CEC criterion that reflects a thin oxic or kandic horizon.

Let me propose the following for your consideration. The intergrade could be Tropeptic if in iso-temperature or Inceptic in non-iso areas.

Inceptic subgroups have a 20 cm or thicker horizon below an oxic or kandic horizon but above 2 m from the surface with either an apparent cation-exchange capacity of the clay fraction *or* a weatherable mineral content too great to meet the requirements of an oxic horizon. Comments?

Andic subgroups have potential importance in several areas in Africa and perhaps Asia according to Wim [Sombroek]. Does anyone have examples that would fit the andic intergrade criteria proposed by ICOMAND (see ICOMOX Circular Letter No. 12)?

Families

Textural Families

Everyone seems in agreement on textural families. (I like to write that.)

Mineralogical Families

Herbillon has carefully considered this question and provides some suggestions I feel have a great deal of merit. I will attempt to relay them.

1. Because of the criteria of the order it is not necessary to specify either siliceous or kaolinitic at the family level, i.e., certainly the siliceous is redundant.
2. The above observation allows us an opportunity to include criteria that are more useful for describing Oxisols than are available in other orders.
3. He suggests we concentrate on developing criteria that reflect the specific reactivity of the minerals on the soil. He uses the phrase "reactivity classes based on or at least related to mineralogical criteria."

4. Examples of such classes, i.e., mineralogical families, that we would suggest (here I am combining his suggestions with concerns expressed by others) are the following and would apply regardless of textural family:

   1: "HIV" (Hydroxy Interlayered Vermiculite)
   The criterion for this family would be the presence of more than 2 meq KCl-exchangeable Al in some part of the mineral control section. Herbillon discussed the fact that HIV minerals vary greatly in their reactivity so an exchangeable-Al criterion is a better indicator of the soil properties than an amount of HIV. I have suggested the 2 meq Al after looking at data from Moniz who worked in Brazil and Mejia who worked in the Llanos of Colombia. Herbillon states "a high exchangable-Al value is a sure mark of the presence of HIV or of similar clay silicates; however, if the cause (here, the content and the nature of these HIV minerals) of this peculiarity is not fitted to serve as diagnostic, then let us select one of the prominent effects, i.e., high exchangeable-Al value." He attributes that logic to John Stuart Mill.

Herbillon proposes one or two gibbsitic classes and two ferritic classes.

Gibbsitic
Schargel would set the criterion at greater than 25 percent gibbsite (whole soil basis?).

Ferritic
An 18-40 percent dithionite citrate (free) Fe_2O_3 on a whole soil basis proposed by Brazil (Circular Letter No. 12) seems reasonable to Schargel, but 13 percent may be a better lower limit in Australia.

"Ferruginous"
A greater than 40 percent dithionite citrate (free) Fe_2O_3 in some part of the control section was not discussed. I suggest the name but expect someone to do better.

Oxidic
Several people have expressed a dislike for the criteria, either that in Soil Taxonomy or the ZPNC criterion proposed in earlier letters. Most have suggested that delta pH or ECEC values be used. You will note that these are the criteria suggested to define the *Akr* great groups. At this time it appears to me that anything that has been proposed for an oxidic family definition is either redundant to higher category definitions or so close to a higher category definition that we run the risk of creating small categories of no practical significance. Unless someone comes up with a significantly new definition, there appears to be no need for oxidic families in Oxisols.

Halloysitic
No comments have been received.

Mineral Family Summary

I believe we need to do some serious thinking about what we want to do with mineral families *within the Oxisols*. By the very nature of the Oxisol order definition, we only have a small portion of the mineral suites that occur in all soils. We need to consider such questions as, What is the central concept of Oxisol mineral families? In some of the other orders *mixed* would seem to fill that position, but certainly the name "mixed" could not be used in Oxisols with the same definition as it is in other orders. As a suggestion, perhaps we could use *oxic* meaning "none of the other families we define, such as gibbsitic, ferritic, ferruginous, or halloysitic." Also, we should not feel obligated to have a large number of, or even any, mineral families if we should decide that there is no practical reason to further segregate soils within the Oxisol subgroups by mineral or mineral-related property or textural family criteria. I will look forward to a wide open discussion of your ideas in the months to come.

Series
Several of the series that have been presented in Circular Letters No. 11 and 12 were addressed in correspondence.

Profiles T320 and T314 from North Queensland, Australia, were incorrectly characterized as perudic. According to MOREG3 data run by van Wambeke, Ray Isbell says they should be udic. Perudic only exists in Western Australia, thus Profile T320 becomes Humic Haplorthox and Profile T314 becomes Typic Akrorthox.

Ray points out that Profile T314 would be a "Rhodic" subgroup if there were a Rhodic subgroup for Akrorthox. I know of no reason for not having a Rhodic subgroup in Akrorthox. I fear I left it out by mistake. If I don't hear any reason to exclude Rhodic from this great group, I'll enter it.

Malanda should be isothermic; Walkamin and Mareeba are hyperthermic is the word from Ray Isbell.

Los Ulmos pedon

Herbillon has requested samples and would like to see such a pedon in an Andic subgroup. Perhaps the ICOMAND committee would consider reducing its proposed requirements of intergrades into the Andisol order? Wim [Sombroeck] wants it classified as an Ando-Dystric Nitosol.

Summary

I think several concerns have been raised in the subgroup and family categories in this series of correspondence. Personally I am delighted that so many of you take the time to share your experience and data. I always worry that I may overlook points in your letters as I try to summarize them into the circular letter. Please, if I have failed to communicate a point you made to me in your letters, write again and tell me of my oversight.

The following descriptions and data have been received and classified according to the 1984 ICOMOX Working Key. This is the real test of the system. Until we all get experience in using the proposed key, we have only debated ideas and concepts. Uniformity and communication will come about when we all are in agreement as to the placement of hard data and descriptions. There is no way I am always correct in what I do in placing these pedons, so check me out.

Appendix I: Profiles T229, T230, T231 and T232

Ray Isbell has provided us with these four pedons [data are included in the original letter] that force us to test the order criteria. The following are the critical properties that I see in the placement of these profiles as related to the present keys.

1. All the profiles fail to have the rate of clay content increase required for kandic horizons but do have the rate of clay content increase with depth needed for an argillic horizon (see results of Frank Moorman's kandic-argillic statistical test provided by Ray).
2. The presence of clay skins and/or clay bridges is doubted by Ray, myself, and several others who have seen some or all of these pedons in the field (i.e., there is severe doubt that we could get *uniform* opinion among soil scientists that these pedons have an argillic horizon).
3. All pedons have horizons within 1 m of the surface that meet the requirements of an oxic horizon. (Note: ECEC/100 g clay, and Ray assures me the Quartzitic sandstones do not have enough weatherable minerals to escape oxic.)
4. None of the pedons have more than 40 percent clay in the surface 18 cm so we do not consider item 2 of the key to order (see Circular Letter No. 12).
5. They all enter Oxisols *if* we do not find an argillic (*a la* evidence of clay translocation), or all escape Oxisols and become sorted as Aridisols or Alfisols via the epipedon being *both* massive and hard. (If *both* massive and hard they become Alfisols and if not they are Aridisols.) (Note: Ray has two of each.)

The ICOMOX question is: Should all of these pedons be Oxisols (Torrox) or not? If we want them as Oxisols, we could consider one of the following changes in the Oxisol order criteria.

a. Change item 1 in statement C (Circular Letter No. 12) to "An oxic horizon with its boundary within 1 m of the soil surface and not overlain by a kandic horizon." [Note: we make no reference to an argillic horizon and then these profiles clearly make Oxisols.] *or*
b. We could be somewhat more exclusive and say in the same statement "An oxic horizon with its boundary within 1 m of the soil surface and not overlain by a kandic horizon or an argillic horizon with a CEC or weatherable mineral content greater than that required by an oxic horizon."

If I correctly remember our concerns in ICOMLAC, the opinion of the group, with several objections, was that in low CEC horizons we wanted to have a greater rate of clay content increase with depth than was provided for in the argillic horizon definition in order to exclude pedons from the Oxisol order, i.e., thus the 1.2x clay increase within 15 cm for the kandic rather than the 1.2x clay increase within 30 cm required for the argillic. If we adopt either of the two suggestions I have made to place these pedons in Oxisols, it will also affect similar morphological pedons in other moisture regimes. As you will see when the official document from USDA-SCS comes out for testing the kandic horizon proposal, we recognized that this could happen but hoped that there would be few pedons.

I'm certain most of us would not consider these as "good" or "modal" Oxisols but like every order there has to be some "fringe pedons" in order to keep the entire system complete. If left to Aridisols and Alfisols they would probably put them in "Alfric," "Argic," or other appropriately defined subgroup or great group. I will await your comments.

Circular Letter No. 14, January 1985

This voluminous "letter" of 86 pages presented data from 19 pedons and tested their ICOMOX placement through the family. Much of the discussion focused on the subgroups and families. A revised 1985 ICOMOX Working Key was presented, and the 19 pedons were described. An additional 22 pedons included in the previous circular letters were classified by the 1985 ICOMOX working key.

The discussions and the key are reprinted from Circular Letter No. 14.

Definitions

Oxic-Kandic Horizon

I presented a review of this at the recent Soil Science Society of America meetings in Las Vegas and a detailed written draft of the ICOMLAC proposal has been circulated to U.S. soil scientists. To my surprise, there were suggestions from the audience that the argillic horizon criteria be changed from "clay content increase of 1.2x within a vertical distance of 30 cm" to "clay content increase within a vertical distance of 15 cm" (i.e., the same as that in the proposed kandic horizon definition). To that end, a memo has been sent from USDA-SCS, Washington, instructing soil scientists in the National Cooperative Soil Survey to review existing soils that approach the Alfisol-Inceptisol class limit. If it is decided that the more rapid rate of clay content increase is satisfactory, it will greatly simplify defining Oxisols with surface 18 cm textures less than 40 percent clay.

Oxic-Andic (Vitric) Horizon

In the forthcoming ICOMAND Circular Letter No. 7 the following will be proposed as a criterion for Andic subgroups:

(Typic subgroups) Do not have, throughout a minimum thickness of more than 18 cm in the upper 75 cm, (a) a bulk density of the fine earth (measured in the field moist state) of less than 1 g/cm^3 and (b) acid oxalate-extractable aluminum of 1 percent or more, or 4*M* KOH-extractable aluminum of 0.75 percent or more.

I have included this change in the 1985 ICOMOX Working Key and propose allowing Andic Kurorthox to be with or without the 5YR or redder colors in some part of the kandic horizon above 1.25 m. The Los Ulmos pedon (Circular Letter No. 12) then becomes an Andic Kurorthox; very-fine, halloysitic, mesic. Comments?

Roger Parfitt and the New Zealand group have provided data on a Naike pedon, which helps focus attention on the Andic end of Oxisols (see Appendix [to this Letter]).

Don Kinloch raises a very interesting point. The Andic subgroup requires both low bulk density and oxalate-extractable Al. Are there any soils (Oxisols) that have vitric materials, which I presume would not

have high enough oxalate Al contents for Andic? I have never seen such soils, but it could be possible after a recent eruption. If no one knows of such pedons, it is best we drop the question.

Clay Content and O.C. Removal

John Kimble raises a question on ECEC measurements when there is no KCl-extractable Al. This usually is true when 1:1 H_2O pH is above 5.2 or more certainly above 5.5. It is our opinion that ECEC becomes the sum of Ca, Mg, K, and NA. Does this cause anyone concern?

Several people questioned the 20-50 micron silt I presented in Circular Letter No. 13. This turns out to be one of my errors. Lepsch writes that the proposal should read silt 2-50 micron . As a compromise with Wim [Sombroek], Lepsch proposes lowering the ratio to less than 0.7 (2-50 micron silt/clay) as an oxic horizon criterion. He included data (Gomes and Antunes 1962) that indicates the less than 0.7 with USDA silt would compare with less than 0.4 via 2-20 micron silt/clay, i.e., international silt. Comments?

Wim [Sombroek] is going to run some "unbiased" laboratory checks on ECEC of oxic horizons both with and without O.C. removed. In this regard, I would call your attention to the results Lopes and Cox (1977) reported: From their some 400 samples of mainly Oxisols in Brazil they found little or no influence on ECEC when o.m. contents were in the 1 to 6 percent range. It appears that O.C. content should not greatly influence ECEC criteria for the oxic horizon unless in "Eutric" great groups.

Elemental Composition, Weatherable Minerals

At present (see Circular Letter No. 10) we have proposed a total elemental analysis limit of less than 40 meq/100 g (cmol (p+) kg^{-1}) in the fine earth. Two items seem to be of concern.

1. How severe is the potential problem of including oxide-coated minerals, which many would not like included? My present thinking is that if we confine the analysis to the less than 2 mm material, there is little concern. Do you agree with this? Then there is the question of whether laboratories routinely doing total elemental analyses use only the less than 2 mm material. I would very much like to have you investigate what is done and has been done in various laboratories.
2. How well does a total elemental analysis limit correspond to weatherable mineral content as determined by optical macroscope and grain counting techniques? Herbillon originally suggested the limit would be between 25 and 40 meq of Ca, Mg, K, and NA/100 g soil. He favors the 25 meq limit based upon data from various soils. However, it would be very good to have some data from samples where both grain counts and total elemental analysis data were available.

The following table may be of help in converting oxide and elemental values to meq values. (Please check my rusty chemistry.)

percent CaO x 35.8 = meq Ca^{++}/100 g
percent MgO x 50.0 = meq Mg^{++}/100 g
percent K_2O x 21.6 = meq K^{+}/100 g
percent Na_2O x 32.2 = meq Na^{+}/100 g

Oxic Horizon

I note that I have not included an oxic horizon definition since Circular Letter No. 8 although there has been considerable discussion. I hope the following summary reflects all the changes since that time; it is, of course, subject to your review.

The oxic horizon is a subsurface horizon that:

1. Is at least 30 cm thick;
2. Has a fine earth fraction (less than 2 mm) that has an apparent ECEC (NH_40Ac) exchangeable bases plus 1*N* KCl-extractable Al/percent clay) less than 12 meq per 100 g clay or has an apparent CEC 7 (NH_40Ac CEC/percent clay) of less than 16 meq/100 g clay;

3. Has an acid-oxalate extractable aluminum value less than 2 percent and a 4*M* KOH-extractable aluminum value less than 1.5 percent;
4. Has less than 10 percent weatherable minerals in the 50-250 micron fraction or less than 40 meq of bases (Ca + Mg + K + Na)/100 g soil total elemental analysis of fine earth (less than 2 mm);
5. Has a sandy loam or finer texture, in the fine earth fraction, and has more than 8 percent clay;
6. Has a diffuse upper textural boundary (i.e., less than 1.2x clay increase within a vertical distance of 15 cm);
7. Has less than 5 percent by volume that shows rock structure unless the lithorelicts containing weatherable minerals are coated with sesquioxides;
8. Has less than 85 percent gravel, by volume.

Key to the Order

There seems to be a concern to allow fluvial materials into the Oxisol order if the material meets all the other criteria. This opens the way for Fluventic subgroups, at least in theory. Perhaps we need not concern ourselves until someone goes out and finds an Oxisol that has morphological evidence of surface flooding (i.e., thin layers of contrasting materials, irregular decrease in carbon content with depth, etc.)

Key to Suborders

I wish to go on record by pointing out that by unanimously agreeing with Pedro Sanchez's suggestion to rename Orthox as Udox, we have set Soil Taxonomy back over 20 years (see 7th Approximation, 1960). I have found no reason for the original conversion of Udox to Orthox that took place between 1960 and 1966. I would personally like to know the reason for the change at that time. Note the change in the key and computer runs. Eutrudox takes a bit of getting used to.

Recently Dr. Walter Couto sent me a manuscript (Couto, Sanzonowicz, and Barcellos) with observations on five pedons of a clayey, oxidic, isohyperthermic, Typic Acrustox (Soil Taxonomy name) soil in the Federal District near Brasília, Brazil. Hopefully, it will soon be published, but the findings are quite disturbing to our concepts of the relationship between low chroma mottles and water table. What they found, in brief, was that oxic horizons, saturated for several months each year, remained 7.5YR 5/6 and eH values were above 500 mV. When the material was taken to containers and saturated for long periods, only samples from the surface 40 cm became reduced. Adding nutrients, thought to limit microbial activity, did not cause reduction. However, adding sucrose caused all samples to reduce. Interestingly, the 40-60 cm samples had as much O.C. as the 20-40 cm samples (12 g/kg) but apparently was too resistant to serve as an energy source. The O.C. in the 0-40 cm layers is apparently less resistant.

The conclusion I reach is that we may have water tables near the surface in Oxisols for prolonged periods of the year but we do not see low chroma colors develop. This may account for a lack of Aquic subgroups.

Great Group Comments

Akr

Igo Lepsch strongly favors increasing the depth to which we look for Akr criteria to 1.5 m. Also, he proposes keying the depth to the bottom of the umbric or mollic epipedon. He proposes Akr great groups as "having some 5 cm or thicker layer within 1.5 m of the surface or within 120 cm of the bottom of an umbric epipedon, if present, with either (1) apparent ECEC equal to or less than 2 meq/100 g of clay plus silt *and* KCl-exchangeable Al content less than 1.5 meq/g soil; or (2) KCl pH greater than or equal to 4.8 and delta pH greater than –0.2 (KCl pH – 1:1 H_2O pH).

Please note that my use of apparent ECEC, or any other "apparent" value with respect to value per amount of clay, as in this case clay plus silt, means the value determined on the whole soil (less than 2 mm fraction) and divided by the content of the fraction. No O.C. is removed in this case. Thus if ECEC is 1 meq/100 g soil and the soil contains 40 percent clay and 10 percent silt, the apparent ECEC is 1/0.5 = 2 meq/100 g silt plus clay. I believe that use of "apparent" is consistent with the rest of Soil Taxonomy.

John Kimble raises an interesting and perhaps very useful point. Why do we always try to characterize the clay in the soil when we are supposed to be classifying the soil? In effect, that is what we are doing when we have expressed criteria on an "apparent" clay, or in the above case silt plus clay basis. This practice is quite self-defeating in Soil Taxonomy because it utilizes similar criteria at more than one categoric level. In this case the mineralogy of the clay is a family criterion. John proposes we simply set an ECEC limit per 100 g whole soil at a specific depth. This also should have a desirable effect on accuracy since only one measurement is involved rather than a ratio of three, difficult to determine, values, i.e., ECEC, percent clay, percent silt.

In this case the rationale would seem to follow that at the great group level we identify those Oxisols with very low subsoil charge, i.e., Akr. This is most likely due to either very coarse-textured Oxisols and/or specific mineral compositions of the fine-textured soils. Some would say apples and oranges. However, at the family level, we will split these "Akr" great groups by both texture and mineral composition.

Just as a value to shoot at, and since most Oxisol data at my fingertips have about 50 percent clay, I propose we take a look at an "Akr" great group value of less than 1 meq/100 g soil ECEC.

I trust that I will receive comments about this point.

I have *not* altered the 1985 ICOMOX Working Key relative to "Akr" great groups pending further discussion.

Kur, Plinth, Eutr, Umbr, Ochr, Hapl

No discussion received except see Kuric subgroups.

Subgroup Comments

Alfic	New in "Eutro" great groups, see Kuric.
Andic	This subgroup has been discussed above. A new limit is proposed by ICOMAND. Note: The Andic subgroup occurs in Kurudox with or without red colors.
Aeric	No comments. See suborder discussion. I was assured during the Brazil soil classification workshop that there was probably a need for Aeric and Aquic in detailed mapping but units are very narrow. Perhaps we can delete one. Comments?
Aquic	No comments. See suborder discussions.
Humic	Deleted from subgroups in Torrox (Isbell suggestion).
Inceptic	A 20 cm or thicker horizon, below an argillic or kandic horizon, but above 2 m from a surface with an apparent CEC of the clay or weatherable mineral content too great to meet oxic horizon requirements. Not included in 1985 ICOMOX Working Key. Please send specific examples. Silt/clay ratio greater than 0.7 (with 2-50 micron silt) or greater than 0.4 (with 2-20 micron silt) proposed by Lepsch. Comments?
Kuric	Kuric great groups only occur in Eutrudox and Eutrustox because they key before the Kurudox and Kurustox in the great group keys. Lepsch points out that such soils intergrade to Alfisols and it is in line with Soil Taxonomy to intergrade to another order. Therefore, see Rhodudalfic and Alfic additions.
Rhodudalfic	New in Eutrudox that have "kandic horizon" clay increase and "Rhodic" requirements. Kandudalfic or Paleudalfic subgroups would be implied if they were not less than 5Y hue. Comments?
Petroferric	No comments; need examples.
Perudic	There are a number of Perudic pedons in the Brazilian data presented in the Appendix. It creates a problem, especially with three subgroup criteria being met, i.e., Perudic, Humic, and Rhodic. For this draft I have coined the word Perudumic for the combination of Perudic and Humic. Perhaps "Humrodic" for Humic and Rhodic would be equally bad. However, we have several other alternatives: *Alternative 1.* Create Perudic suborders. Advantages are that Perudic fits well into criteria used at the suborder level in Oxisols and other orders. It also creates geographic significance to suborders. *Um* from Latin *humidus* (humid) could be the formative element, i.e., Umox, Kurumox, Akrumox, Halumox.

	Alternative 2. Recreate the Humox suborder, confining it to udic and perudic soil moisture regimes and recognizing Perudic subgroups. If this were considered I would suggest we simplify the definition to reduce the analysis required. Present Soil Taxonomy Humox requires O.C. and bulk density be determined in all horizons to a depth of 1 m. It could be only an umbric, mollic, or histic epipedon. A color criterion is desirable in the field.
	Alternative 3. Do not use Perudic as a classification criterion.
	Alternative n. Open to your creativity. I urgently need your comments on this one.
Rhodic	The Brazilians are proposing much finer splits regarding color in their Latosols. They may wish to have more color subgroups in Oxisols. No formal comments received.
Vitric	Proposed and defined by ICOMAND. No known use in Oxisols (see discussions above).
Lithic	Need examples.
Plinthic	Need examples.

Families

Control section

The statement in Circular Letter No. 12 and on the computer key defining this as 20-100 cm, etc. appears to be one of my errors. It should read "25-100 cm," unless someone knows of some great wisdom that caused us to be different in Oxisols.

Texture families

Very fine, fine, fine-loamy, and coarse-loamy all seem to be favored by everyone.

Mineralogy families

My thanks, I think, to the many of you who responded with discussions of what we may want to do with mineralogy families in Oxisols. What I didn't find was an absolute, divinely conceived system. As I try to put together the several points conveyed in your letters, I am in great need of divine intervention. What I propose to test this next year is as follows:

> "HIV" mineral family (Allic, see later) for use in any textural family of Oxisols; criterion is "more than 1 meq KCl-extractable Al per 100 g of whole soil (fine earth fraction, i.e., less than 2 mm) in some 30 cm thickness within the 25-100 cm control section depth."

I would venture that the criterion of 2 meq Al has some rather fundamental influence on our soil management ability to improve the subsoil as a medium for plant growth. It will be difficult to equate exchangeable Al to HIV content because we are not easily able to quantify HIV content. Also, as Lepsch points out, we will most likely be creating a family into which some pedons with no HIV will be placed. Pedon T320 is one of these. Also, Ray Isbell provided an example of a soil with more than 3.6 meq Al in which Gavin Gillman found no HIV. He suggests that HIV mineralogy will create more than 1 meq Al but the converse, i.e. greater than 2 meq Al means HIV, will not always be true. Thus, for comment I propose to use "Allic families" in Oxisols for any Oxisol that has more than 2 meq KCl-extractable Al per 100 g of whole soil (fine earth fraction, i.e, less than 2 mm) in some 30 cm thickness within the 25-100 cm control section depth.

This name may conflict with Brazilian use of the same name based on Al saturation of the CEC. Comments from Brazil: The advantage is that it does connote what we are using for a criterion and the criterion reflects a management concern, namely the amount of lime required to alter the subsoil conditon, which is one of the family criteria objectives. From a purist point of view, this may better be considered a reaction family with mineral connotations.

Halloysitic families

Joe Whitton of New Zealand comments that we should seriously consider if we need a halloysitic mineral family. It is a good question. I suspect the desirability comes from physical (engineering) properties, but I need some data to justify that halloysite content is responsible for certain soil properties.

I think we would retain halloysitic families, and I strongly suggest we use the Formamide test described by Churchman et al. (1983) to test some of our key pedons. In case you don't have Soil Taxonomy News No. 5, you can also refer to Churchman et al. (1984).

The 50 percent limit has not been discussed and needs testing.

Siliceous family

It has been pointed out that this is certainly a redundant designation in the Oxisols and should be dropped. Comments? It will be dropped for the 1985 ICOMOX Working Key.

Gibbsitic family

The greater than 25 percent gibbsite on a *whole soil basis* seems to find favor with several respondents. DTA analysis of the whole soil is the recommended procedure.

Ferruginous family

The limit of more than 40 percent Fe_2O_3 with a dithionite citrate extract is higher than that used in Brazil since they use the sulfuric acid (d = 1.47) procedure. Data by Melo et al. presented at the soil classification workshop in Brazil in 1984 indicates that, on a whole soil basis, the ratio of dithionite citrate-extractable iron to sulfuric acid-extractable iron ranges from 0.94 to 0.63. An average ratio is approximately 0.80.

Therefore, I suggest we define a ferruginous family as more than 40 percent Fe_2O_3 with sulfuric acid (d = 1.47) or more than 32 percent Fe_2O_3 with dithionite citrate on a whole soil fine earth fraction.

Ferritic families

Following the same reasoning, ferritic families would have from 18 to 40 percent Fe_2O_3 on the whole soil via the sulfuric acid (d = 1.47) extract or between 14 and 32 percent Fe_2O_3 via a dithionite citrate extract.

Note: The above raises the possibility of gibbsitic and ferritic conditions both being attained. For the present, we could propose a double family name. This is also true for allic-ferritic.

Thus for ICOMOX 1985 testing, the following is proposed:

Ferruginous =	more than 40 percent Fe_2O_3 by sulfuric acid or more than 32 percent Fe_2O_3 by dithionite citrate (less than 2 mm).
Ferritic =	18-40 percent Fe_2O_3 by sulfuric acid or 14-32 percent Fe_2O_3 by dithionite citrate (less than 2 mm).
Gibbsitic =	more than 25 percent gibbsite by DTA (whole soil).
Halloysitic =	more than 50 percent halloysite (less than 2 micron fraction).
Allic =	more than 2 meq KCl-extractable Al in some 30 cm layer within the control section.
(Multifamily) =	two or more of above if found, for example: Ferritic-Allic; Ferritic-Gibbsitic. Kaolinitic = none of the above. Note: Kaolinitic then becomes a family in any textural family, i.e., fine-loamy, kaolinitic.
Textural families:	No changes proposed.
Temperature families:	No changes proposed.

Comments on Series (Pedons) in ICOMOX File

I have quickly rechecked the pedons from previous circular letters against the proposed 1985 ICOMOX Working Key with the following results. (I hope others of you will check my placement against the data.)

Typic Akrustox; fine, kaolinitic isohyperthermic

Meheba - Circular Letter No. 13

Meheba, acric phase - Circular Letter No. 13

Chafuguma - Circular Letter No. 13

NWP/82/1 - Circular Letter No. 13

Samfya - Circular Letter No. 13

Typic Akrustox; fine-skeletal, kaolinitic, isohyperthermic
Profile #72 - Circular Letter No. 13
Rhodustalfic Eutrustox; fine, kaolinitic, hyperthermic
Mareeba - Circular Letter No. 11
Wilkamin - Circular Letter No. 11
Typic Haplustox; coarse-loamy, kaolinitic, isohyperthermic
Profile Cha 77 - Circular Letter No. 13
Typic Haplustox; fine, kaolinitic, isohyperthermic
Profile L-Schargel - Circular Letter No. 13
Kasempa - Circular Letter No. 13
Rhodic Haplustox; fine, ferritic, isohyperthermic
Meumena - Circular Letter No. 13
Rhodic Haplustox; very-fine, kaolinitic, isohyperthermic
Mehcba-NWP/ADP/016/82 - Circular Letter No. 13
Rhodic Akrudox; fine, ferritic, hyperthermic
Jardinopolis: Profile 1350-
Rhodic Akrudox; very-fine, ferritic-gibbsitic, isohyperthermic
Profile T314 - Circular Letter No. 11
Rhodic Akrudox; very-fine, ferritic, isohyperthermic
Malanda Profile T62 - Circular Letter No. 11
Profile E - Schargel - Circular Letter No. 13
Rhodudalfic Eutrudox; very-fine, ferritic, hyperthermic
Profile 1.210 - Circular Letter No. 11
Andic Kurudox, very-fine, halloysitic, mesic
Los Ulmos - Circular Letter No. 13
Typic Hapludox; fine, allic, hyperthermic
Pariquera - Circular Letter No. 11
Humic Hapludox; very-fine, allic, isohyperthermic
Profile T320 - Circular Letter No. 11
Humic Rhodic Hapludox; fine-loamy, allic, thermic
Profile 1.032 - Circular Letter No. 11

Summary

Of the questions raised, I particularly need your comments and opinions on the use of perudic soil moisture regime (i.e., precipitation exceeds potential evapotranspiration every month of most years) at the suborder level. Also, the soil family criteria need some rigorous testing. I encourage you to provide some examples of Petroferric, Lithic, Aquic, and Plinthic subgroups and the Aquox suborder.

I have just been informed that one of our group, Prof. Dr. J. Bennema, Professor of Tropical Soil Science, at the Agricultural University, Wageningen, The Netherlands, died approximately Janaury 7, 1985. His contributions to Soil Science are many. He participated in the many International Committee Workshops and actively engaged in the discussions at the sites of the 14 Brazilian pedons presented in the following Appendices [in the original letter] during the September 1984 Brazilian Soil Science Conference.

His counsel will be missed, his contributions cherished, his passing mourned, but the fact of his being, celebrated.

Oxisol Key

Order Key Statement C: (To key after Histisols, Spodosols, and the proposed Andisols) 1985 ICOMOX Working Key:

Other soils that either have:

1) An oxic horizon with its upper boundary within 1 m of the soil surface and is not overlain by an argillic or kandic horizon, or
2) 40 percent or more clay in the surface 18 cm, after mixing, and either an oxic horizon *or* a kandic horizon with an apparent CEC of the clay fraction less than 16 meq/100 g clay (NH_4OAc) or an apparent ECEC of the clay (bases plus KCl Al) less than 12 meq/100 g clay, with an upper boundary within 1 m of the soil surface and meeting the weatherable mineral and rock fragment requirement of an oxic horizon.

Key to Oxisol Suborders (1984 ICOMOX Working Key)

CA Is this Oxisol either saturated with water within 30 cm of the mineral surface 30 days per year in most parts or artificially drained and have either:
1) A histic epipedon, or
2) If not mottled, a moist color value less than 3.5 and a dominant chroma or 2 or less immediately below any epipedon, or
3) If there are distinct or prominent mottles within 50 cm of the surface, a dominant chroma of 3 or less or a hue of 2.5Y or yellower?

If yes Aquox

CB Does this Oxisol have an aridic soil moisture regime?

If yes Torrox

CC Does this Oxisol have an ustic or a xeric soil moisture regime?

If yes Ustox

CD If no to all above:

Udox

Aquox Key

CAA Does this Aquox have an apparent ECEC of less than 1.5 meq/100 g clay in the oxic horizon and within 2 m of the surface?

If yes Akraquox

CAB Does this Aquox have plinthite forming a continuous phase within 1.25 m of the soil surface?

If yes Plinthaquox

CAC Does this Aquox have an umbric, mollic, or histic epipedon?

If yes Umbraquox

CAD If no to all above:

Ochraquox

Torrox Key

CBA Does this Torrox have an apparent ECEC of less than 1.5 meq/100 g clay in the oxic horizon within 2 m of the soil surface?

If yes Akritorrox

CBB Is this Torrox more than 35 percent base saturated (NH_4OAc) in all parts to a depth of 1.25 m?

If yes Eutrotorrox

CBC If no to all above.

Haplotorrox

Ustox key

CCA Does this Ustox have an apparent ECEC of less than 1.5 meq/100 g clay in the oxic horizon within 2 m of the soil surface?

If yes Akrustox

CCB Is this Ustox more than 35 percent base saturated (NH_4OAc) in all parts to a depth of 1.25 m?

If yes Eutrustox

CCC Does this Ustox have more than 40 percent clay in the surface 18 cm after mixing, and a clay content increase with depth of more than 8 percent, absolute, within a thickness of 15 cm occurring within 1.5 m of the surface?

If yes Kurustox

CCD If no to all above:

Kaplustox

Udox key

CDA Does this Udox have an apparent ECEC of less than 1.5 meq/100 g clay in the oxic horizon within 2 m of the soil surface?

If yes Akudox

CDB Is this Udox more than 35 percent base saturated (NH_4OAc) in all parts to a depth of 1.25 m?

If yes Eutrudox

CDC Does this Udox have more than 40 percent clay in the surface 18 cm after mixing, and a clay content increase with depth of more than 8 percent, absolute, within a thickness of 15 cm occurring within 1.5 m of the surface?

If yes Kurudox

CDD If no to all above:

Hapludox

Great Group Keys

Akraquox:

Does this Akraquox have:

1) An ochric epipedon?
2) More than 5 percent plinthite in some layer within 1.25 m of the soil surface?
0) None of the above?

1 = Ochreptic Akraquox
2 = Plinthic Akraquox
0 = Typic Akraquox

Plinthaquox:

Does this Plinthaquox have:

1) An ochric epipedon?
0) None of the above?

1 = Ochreptic Plinthaquox
0 = Typic Plinthaquox

Umbraquox:

Does this Umbraquox have:

1) Chromas of more than 2 in the horizon immediately below the epipedon?
2) More than 5 percent plinthite in any horizon within 1.25 m of the surface?
3) Base saturation more than 35 percent (NH_4OAc) in all parts above 1.25 m?
0) None of the above?

1 = Aeric Umbraquox
2 = Plinthic Umbraquox

3 = Eutric Umbraquox
0 = Typic Umbraquox

Ochraquox:
Does this Ochraquox have:
1) Chromas of more than 2 in the horizon immediately below the epipedon?
2) More than 5 percent plinthite in some horizon above 1.25 m?
3) Base saturation more than 35 percent (NH_4OAc) in all parts above 1.25m?
0) None of the above?
1 = Aeric Ochraquox
2 = Plinthic Ochraquox
3 = Eutric Ochraquox
0 = Typic Ochraquox

Akritorrox:
Does this Akritorrox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
0) None of the above?
1 = Petroferric Akritorrox
2 = Lithic Akritorrox
0 = Typic Akritorrox

Eutrotorrox:
Does this Eutrotorrox have;
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
0) None of the above?
1 = Petroferric Eutrotorrox
2 = Lithic Eutrotorrox
0 = Typic Eutrotorrox

Haplotorrox:
Does this Haplotorrox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
0) None of the above?
1 = Petroferric Haplotorrox
2 = Lithic Haplotorrox
0 = Typic Haplotorrox

Akrustox:
Does this Akrustox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) Mottles of 2 or less chroma within 1.25 m of the soil surface?
4) More than 5 percent plinthite in some horizon above 1.25 m?
0) None of the above?
1 = Petroferric Akrustox
2 = Lithic Akrustox
3 = Aquic Akrustox
4 = Plinthic Akrustox
0 = Typic Akrustox

Eutrustox:
Does this Eutrustox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) Mottles of 2 or less chroma within 1.25 m of the soil surface?
4) More than 5 percent or more plinthite in some horizon above 1.25 m?
5) A mollic or an umbric epipedon?
6) Color hues redder than 5YR in some part of the oxic horizon above 1.25 m?
7) More than 40 percent clay in the surface 18 cm after mixing and the top of a kandic horizon within 1.5 m?
0) None of the above?
1 = Petroferric Eutrustox
2 = Lithic Eutrustox
3 = Aquic Eutrustox
4 = Plinthic Eutrustox
5 = Humic Eutrustox
6 = Rhodic Eutrustox
7 = Alfric Eutrustox
6 and 7 = Rhodustalfic Eutrustox
0 = Typic Eutrustox

Kurustox:
Does this Kurustox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) Mottles of 2 or less chroma within 1.25 m of the soil surface?
4) More than 5 percent plinthite in some horizon above 1.25 m?
5) A mollic or an umbric epipedon?
6) Color hues redder than 5YR in some part of the oxic horizon above 1.25 m?
0) None of the above?
1 = Petroferric Kurustox
2 = Lithic Kurustox
3 = Aquic Kurustox
4 = Plinthic Kurustox
5 = Humic Kurustox
6 = Rhodic Kurustox
5 and 6 = Humic Rhodic Kurustox
0 = Typic Kurustox

Haplustox:
Does this Haplustox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) Mottles of 2 or less chroma within 1.25 m of the soil surface?
4) More than 5 percent plinthite in some horizon above 1.25 m of the soil surface?
5) A mollic or an umbric epipedon?
6) Color hues redder than 5YR in some parts of the oxic horizon above 1.25 m?
0) None of the above?
1 = Petroferric Haplustox
2 = Lithic Haplustox
3 = Aquic Haplustox
4 = Plinthic Haplustox
5 = Humic Haplustox

6 = Rhodic Haplustox
0 = Typic Haplustox

Akrudox:
Does this Akrudox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) Mottles of 2 or less chroma with 1.25 m of the soil surface?
4) More than 5 percent plinthite in some horizon above 1.25 m?
5) A perudic soil moisture regime?
6) A mollic or an umbric epipedon?
7) Color hues redder than 5YR in some parts of the oxic horizon above 1.25 m?
0) None of the above?
1 = Petroferric Akrudox
2 = Lithic Akrudox
3 = Aquic Akrudox
4 = Plinthic Akrudox
5 = Perudic Akrudox
6 = Humic Akrudox
7 = Rhodic Akrudox
5 and 6 = Perudic Humic Akrudox
6 and 7 = Humic Rhodic Akrudox
5, 6, and 7 = Perudhumic Rhodic Akrudox
0 = Typic Akrudox

Eutrudox:
Does this Eutrudox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) Mottles of 2 or less chroma within 1.25 m of the soil surface?
4) More than 5 percent plinthite in some horizon above 1.25 m?
5) A perudic soil moisture regime?
6) A mollic or an umbric epipedon?
7) Color hues redder than 5YR in some part of the oxic horizon above 1.25 m?
8) More than 40 percent clay in the surface 18 cm after mixing and the top of a kandic horizon within the 1.5 m depth?
0) None of the above?
1 = Petroferric Eutrudox
2 = Lithic Eutrudox
3 = Aquic Eutrudox
4 = Plinthic Eutrudox
5 = Perudic Eutrudox
6 = Humic Eutrudox
7 = Rhodic Eutrudox
8 = Alfic Eutrudox
7 and 8 = Rhodudalfic Eutrudox
0 = Typic Eutrudox

Kurudox:
Does this Kurudox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) Mottles of 2 or less chroma within 1.25 m of the soil surface?
4) More than 5 percent plinthite in some horizon above 1.25 m?

5) A perudic soil moisture regime?
6) A mollic or an umbric epipedon?
7) Color hues redder than 5YR in some part of the kandic horizon above 1.25 m?
8) An 18 cm or thicker layer in the upper 75 cm with a bulk density less than 1 g/cc *and* either an acid oxalate Al content more than 1 percent or 4*M* KOH-extractable Al of 0.75 percent or more?
0) None of the above?
1 = Petroferric Kurudox
2 = Lithic Kurudox
3 = Aquic Kurudox
4 = Plinthic Kurudox
5 = Perudic Kurudox
6 = Humic Kurudox
7 = Rhodic Kurudox
6 and 7 = Humic Rhodic Kurudox
8 with or without 7 = Andic Kurudox
0 = Typic Kurudox

Hapludox:
Does this Hapludox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) Mottles of 2 or less chroma within 1.25 m of the soil surface?
4) More than 5 percent plinthite in some horizon above 1.25 m?
5) A perudic soil moisture regime?
6) A mollic or umbric epipedon?
7) Color hues redder than 5YR in some part of the oxic horizon above 1.25 m?
0) None of the above?
1 = Petroferric Hapludox
2 = Lithic Hapludox
3 = Aquic Hapludox
4 = Plinthic Hapludox
5 = Perudic Hapludox
6 = Humic Hapludox
7 = Rhodic Hapludox
5 and 6 = Humic Perudic Hapludox
5, 6, and 7 = Perudhumic Rhodic Hapludox
6 and 7 = Humic Rhodic Hapludox
0 = Typic Hapludox

Textural Family
(Weighted average of texture between 25 cm and 1 m or lithic or paralithic contact, whichever is shallower.)
1) Less than 18 percent clay.
2) 18 to 34.9 percent clay.
3) 35 to 59.9 percent clay.
4) 60 percent or more clay. (If more than 35 percent gravel or coarser material, add skeletal to name below.) (Contrasting families possible, see Soil Taxonomy.)
1 = coarse-loamy
2 = fine-loamy
3 = fine
4 = very fine

Mineralogical Family (same depth as Textural Family)
1) More than 40 percent iron oxide (28 percent Fe) by sulfuric acid or 32 percent by dithionite citrate.
2) 18-40 percent Fe_2O_3 by sulfuric acid or 14-63.2 percent Fe_2O_3 by dithionite citrate.

3) More than 25 percent gibbsite on whole soil basis.
4) More than 50 percent halloysite.
5) More than 2 meq/100 g clay KCl-extractable Al in some 30 cm layer of the control section.
6) None of the above.

1 = Ferruginous
2 = Ferritic
3 = Gibbsitic
4 = Halloysitic
5 = Allic
1 and 3 = Ferruginous-Allic
2 and 3 = Ferritic-Gibbsitic
2 and 5 = Ferritic-Allic
6 = Kaolinitic

Circular Letter No. 15, July 1985

ICOMOX now had its sights set on the completion of its task of revising Oxisols. Some 50 pedon data sets were received since Circular Letter No. 14 and classified according to the 1985 ICOMOX Working Key. The exercise of keying these pedons revealed some problems in the key and prompted some specific recommendations and solicited early responses so that a 1986 ICOMOX Working Key could be prepared well before the scheduled ICOMOX meeting in Brazil. These points are printed here from Circular Letter No. 15.

Timetable

July 1985	ICOMOX Circular Letter No. 15.
October 1985	Comments on Circular Letter No. 15 needed by me.
November-December 1985	Preparation of "Final Draft ICOMOX Key."
December 1985	Send "Final Draft ICOMOX Key" as Circular Letter No. 16 to ICOMOX Committee.
February 1986	I need to receive comments from those not planning to attend the Brazil meeting. Those attending hopefully will receive the data from the pedons we will see in Brazil and come to the meeting prepared to focus on final preparation of the proposal that will be submitted to the Soil Survey Staff.
March 1986	As soon as the proposal, resulting from the meeting in Brazil, is completed, "ICOMOX hibernates" as the proposal is more widely circulated for testing.

Thus, our present mode of correspondence via circular letters is nearing completion. Make your best arguments for your pet bias, and I'll try my best to formulate a workable key that pleases as many points of view as possible.

Discussion

The following are points I intend to change in the material as presented in Circular Letter No. 14. (You will probably need to have a copy of Circular Letter No. 14 to follow my proposed changes.)

I hope you have noted two items in the above sentence. First, I am raising these points not only in response to the concerns raised by others but also because I have found them troubling as I worked to key

out several pedons. Second, unless you can convince me of a better way, this is what I *intend* to do in the final draft. Now is the time for you to point out the error of my ways.

Oxic Horizon

Point 3 can be deleted. (We find that CEC limits and weatherable mineral limits make this point unneeded.) Comments?

Point 2 dealing with apparent charge on the clay can be expanded to include the following:

"or an ECEC to 15-bar water percentage ratio less then 30 or a CEC (NH_4OAc pH 7 method) to 15-bar water percentage ratio less than 40."

This calculation was produced from several U.S. Oxisol data. It provides an alternative measurement when clay percentage is suspect because of dispersion problems. Comments?

Order Key Statement C

Change to read:

"An oxic horizon with its upper boundary within 1 m of the soil surface and the upper boundary of an argillic or kandic horizon is not present within a depth of 2 m."

(This is believed necessary to avoid having soils that would best be Ultisols or Alfisols with low-activity clays, i.e., the proposed Kandi great groups, classify as Oxisols if so much as 30 cm of what most would identify as an E horizon meet the oxic horizon criteria.) Comments?

If the CEC/15-bar water ratios discussed in the oxic horizon criteria are accepted, they would need to be included here also.

Key to Oxisol Suborders

Add: Suborder "Umox" for perudic soil moisture regimes.

Change to read:

CD Does this Oxisol have a perudic soil moisture regime?

If yes Umox

CE All other Oxisols.

Udox

(Although this recognition of perudic has not been used in other orders, it probably has equal implications there also. The Agro-Ecological Report of FAO places a great deal of significance on extremely humid areas because of the difficulty in finding a time to harvest grain crops without expensive drying facilities.) See Perudic discussion, Circular Letter No. 14.

If we decide to go forward with the Umox suborder, I suspect that the great groups will be essentially the same as those in the Udox suborder.

Color

Now for the big one! At various times in the ICOMOX discussions, the subject of color criteria has been raised. More often this question has been raised verbally. There is no doubt that the Brazilians, the owners of a large proportion of the world's Oxisols, consider color of the well-drained Oxisols a significant criterion. Presently, they consider it at the highest category of their proposed National Soil Taxonomy.

Perhaps we have all been a bit intimidated by the statement on page 9 of Soil Taxonomy: "Color *per se* seems to have no accessory characteristics." From several studies we now know hues of red and yellow can be related to the proportion of hematite and goethite in the soil material. Certain P sorption relationships can be related to these minerals. Finally, color is a feature of soils that is obvious to everyone and thereby a very useful feature to relate to when discussing soils with non-soil scientists.

I believe that red-yellow hues are best recognized at the subgroup level. One major advantage for this is that before we get to subgroup we have identified extremely low CEC "Acr," high base status "Eutro," and certain other properties that are probably more important but less obvious than color. Thus we have considered the "hidden" chemical properties and are now ready to use more obvious but perhaps less significant properties. This I believe to be a real advantage in explaining the usefulness of Soil Taxonomy to users of the soil.

For the above reasons, which at one time or another have been conveyed to me by ICOMOX members, I suggest the following.

For *all* great groups of Ustox, Udox, Torrox and Umox, we use the following two subgroups. (Actually three subgroups, because Typic fits between Rhodic and Xanthic.)

Rhodic: Hues of 2.5YR and redder with moist values less than 4 in most parts of the control section.

Xanthic: Hues of 7.5YR and yellower with moist values of 6 or more in most parts of the control section.

Typic: With respect to color, Typic would be centered on 5YR but include the high value reds, not dusky red or dark red 10R and 2.5YR subsoils and the brown and strong brown 7.5YR and brown and yellowish brown 10YR subsoils. It is probable that many soils with the brown control sections would have umbric or mollic epipedons and be Humic subgroups.

These changes would rename quite a number of the ICOMOX classified pedons. In "most parts of the control section" would be "in more than 40 cm of the 20-100 cm depth." Perhaps a greater thickness could be specified, but it appears to me that would lead to greater uncertainty and color variations at greater depth are best left to series criteria where they have local importance. Comments?

Families

Few have commented on the families as structured in Circular Letter No. 14. Most seemed satisfied except there is some uncertainty about total iron, H_2SO_4 d = 1.47, iron and dithionite-extractable iron relative values. These relative values may need to be slightly altered as checking of data is done. Personally, I found no problems in the pedons I have classified.

Summary

It is now approaching that time where our work must be finalized and submitted as a formal proposal to improve Soil Taxonomy. I hope that I have fairly represented your points of view in the various letters. Please express any differences you may have with the positions I have taken in this letter or in any of the other sections of the ICOMOX Working Key.

I hope that after considering your responses to this letter, I will be able to assemble a draft of the ICOMOX proposal that will be fundamentally acceptable to most, if not all, of you prior to our final session in March 1986.

Circular Letter No. 16, January 1986

The ICOMOX timetable was set back because the workshop in Brazil was delayed until May 1986. Following a brief presentation of reaction to certain items, a 1986 ICOMOX Working Key was presented for testing at the workshop. These portions of the circular letter are reproduced in Circular Letter No. 16. The placement of some 100 pedons according to this key was also reproduced in the Letter but are not reprinted here.

Objectives of ICOMOX Circular Letter No. 16

Following is a draft of the ICOMOX Oxisol key for 1986. It is hoped that it will serve as a draft for the final proposal from ICOMOX. Also enclosed are nearly 100 pedons that you have sent and the placement I have made in the proposed key. I'm sorry that I cannot reproduce all the data for each of you but I'm sure you understand the volume of reproduction and mailing that would involve.

I hope that each of you will check my placement of the particular pedons you have submitted against the enclosed key and call my attention to any mistakes I have made. (I am sure there must be some mistakes because I have not had time to recheck much of my work.)

Also, if you feel strongly that the key has problems for any reason, please voice your concerns as soon as possible. And, as always, your help in getting out editorial errors of spelling, format, etc. are always welcome.

Major Alterations Since Circular Letters Nos. 14 and 15

I will not take time to detail the correspondence relative to these points, but I certainly appreciate the input of Rudy Dudal, Frank Moorman, Hari Eswaran, Ray Isbell, Wim Sombroek, Don Kinloch, Richard Schargel, Igo Lepsch, Adrien Herbillon, Roger Parfitt, Richard Fenwick, Joe Nichols, and I'm sure I forgot a few others that have responded to Circular Letter No. 15.

As it should be, there are differences of opinion and there is probably no right or wrong way to organize a classification system. Of the points raised in Circular Letter No. 15, the following conclusions have been reached.

1. *Not* to use an ECEC ratio to 15-bar water as an oxic horizon criterion. Hope is expressed that we will concentrate on improving our laboratory ability to determine correct, consistent, and reproducible particle-size analyses.
2. Key to Oxisols

   "An oxic horizon with its upper boundary within 1 m of the soil surface and the upper boundary of an argillic or kandic horizon is not present within a depth of 2 m."

   Note: This criterion is used only for Oxisols with less than 40 percent clay in the upper 18 cm after mixing. Also, there is much work going on to examine the possibility of redefining the rate of clay

content increase with depth for the argillic to conform to that required for the kandic, i.e., greater than 1.2 within the 15-cm depth. If this is done, additional pedons will classify as Oxisols.

3. Perudic suborder (Perox)
   Most agree but prefer to not confuse the name with the present Humox. Therefore, the suborder is called "Perox."
4. Xanthic-Rhodic-Typic subgroups
   Generally, this proposal was supported. I admit I did not like it, but after reviewing several soil survey reports from Brazil, I now believe it may have merit. (Note pedons from the lower Amazon Basin that classify as Xanthic. The "most parts of the control section" phrase has been changed to read "most of the 25-100 cm depth").

Summary

I am sorry about the uncertainty of the Brazilian meeting but decided to keep the circular letters more or less on schedule. I feel certain we need to function as a committee until our final proposal is submitted. Therefore, you will hear from me within the next 6 months as I learn what will happen with respect to the pedons sampled in Brazil and the planned meeting there.

In the interim, review the following ICOMOX key, check the pedon placements I have made, and do not hesitate to express your opinion about needed changes. I have all keys, with the pedons referenced, on IBM-PC floppy disk. If any of you would like to work with a copy, let me know. I will continue to add pedons to the files, so if you can supply a set of pedon data to support placement of an Oxisol, especially for families not now represented, please do so.

Appendix I.
ICOMOX Key

Order Key Statement C: (To key after Histosols, Spodosols, and the proposed Andisols) (1986 ICOMOX Working Key)

Other soils that either have:

1) An oxic horizon with its upper boundary within 1 m of the soil surface and do not have a clay content increase necessary to define the upper boundary of an argillic or kandic horizon within a depth of 2 m, or
2) 40 percent or more clay in the surface 18 cm, after mixing, and either an oxic horizon *or* a kandic horizon with an apparent CEC of the clay fraction less than 16 meq/100 g clay (NH_4OAc) or an apparent ECEC of the clay (bases plus KCl Al) less than 12 meq/100 g clay, with an upper boundary within 1 m of the soil surface and meeting the weatherable mineral and rock fragment requirement of an oxic horizon.

Key to Oxisol Suborders (1986 ICOMOX Working Key)

CA Is this Oxisol either saturated with water within 30 cm of the mineral surface 30 days per year in most years or artificially drained and does it have either:

1) A histic epipedon, or
2) If not mottled, a moist color value less than 3.5 and a dominant chroma of 2 or less immediately below any epipedon, or
3) If there are distinct or prominent mottles within 50 cm of the surface, a dominant chroma of 3 or less or a hue of 2.5Y or yellower?

If yes Aquox

CB Does this Oxisol have an aridic soil moisture regime?

If yes Torrox

CC Does this Oxisol have an ustic or a xeric soil moisture regime?

If yes Ustox

CD Does this Oxisol have a perudic soil moisture regime?

If yes Perox

CE If no to all above:

Udox

Aquox key

CAA Does this Aquox have an apparent ECEC of less than 1.5 meq/100 g clay in the oxic horizon and within 2 m of the surface?

If yes Akraquox

CAB Does this Aquox have plinthite forming a continuous phase within 1.25 m of the soil surface?

If yes Plinthaquox

CAC Does this Aquox have an umbric, a mollic, or a histic epipedon?

If yes Umbraquox

CAD If no to all above:

Ochraquox

Torrox key

CBA Does this Torrox have both an apparent ECEC of less than 1.5 meq/100 g clay in the oxic horizon within 2 m of the soil surface?

If yes Akritorrox

CBB Is this Torrox more than 35 percent base saturated in all parts to a depth of 1.25 m?

If yes Eutrotorrox

CBC If no to all above:

Haplotorrox

Ustox key

CCA Does this Ustox have both an apparent ECEC of less than 1.5 meq/100 g clay in the oxic horizon within 2 m of the soil surface?

If yes Akrustox

CCB Is this Ustox More than 35 percent base saturated (NH_4OAc) in all parts to a depth of 1.25 m?

If yes Eutrustox

CCC Does this Ustox have more than 40 percent clay in the surface 18 cm after mixing, and a clay content increase with depth of more than 8 percent, absolute, within a thickness of 15 cm occurring within 1.5 m of the surface?

If yes Kurustox

CCD If no to all above:

Haplustox

Perox key

CDA Does this Perox have an apparent ECEC of less than 1.5 meq/100 g clay in the oxic horizon within 2 m of the soil surface?

If yes Akroperox

CDB Is this Perox more than 35 percent base saturated (NH_4OAc) in all parts to a depth of 1.25 cm?

If yes Eutroperox

CDC Does this Perox have more than 40 percent clay in the surface 18 cm, after mixing, and a clay content increase of more than 8 percent, absolute, within a thickness of 15 cm occurring within 1.5 m of the surface?

If yes Kuriperox

CDD If no to all above:

Haploperox

Udox key

CEA Does this Udox have an apparent ECEC of less than 1.5 meq/100 g clay in the oxic horizon within 2 m of the soil surface?

If yes Akrudox

CEB Is this Udox more than 35 percent base saturated (NH_4OAc) in all parts to a depth of 1.25 m?

If yes Eutrudox

CEC Does this Udox have more than 40 percent clay in the surface 18 cm after mixing, and a clay content increase with depth of more than 8 percent, absolute, within a thickness of 15 cm occurring within 1.5 m of the surface?

If yes Kurudox

CED If no to all above:

Hapludox

Great Group Keys

Akraquox:
Does this Akraquox have:
1) An ochric epipedon?
2) More than 5 percent plinthite in some layer within 1.25 m of the soil surface?
0) None of the above?
1 = Ochreptic Akraquox
2 = Plinthic Akraquox
0 = Typic Akraquox

Plinthaquox:
Does this Plinthaquox have:
1) An ochric epipedon?
0) None of the above?
1 = Ochreptic Plinthaquox
0 = Typic Plinthaquox

Umbraquox:
Does this Umbraquox have:
1) Chromas of more than 2 in the horizon immediately below the epipedon?
2) More than 5 percent plinthite in any horizon within 1.25 m of the soil surface?
3) Base saturation More than 35 percent (NH_4OAc) in all parts above 1.25 m?
0) None of the above?
1 = Aeric Umbraquox
2 = Plinthic Umbraquox
3 = Eutric Umbraquox
0 = Typic Umbraquox

Ochraquox:
Does this Ochraquox have:
1) Chromas of more than 2 in the horizon immediately below the epipedon?
2) More than 5 percent or more plinthite in some horizon above 1.25 m?

3) Base saturation more than 35 percent (NH_4OAc) in all parts above 1.25 m?
0) None of the above?
1 = Aeric Ochraquox
2 = Plinthic Ochraquox
3 = Eutric Ochraquox
0 = Typic Ochraquox

Akritorrox:
Does this Akritorrox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
0) None of the above?
1 = Petroferric Akritorrox
2 = Lithic Akritorrox
0 = Typic Akritorrox

Eutrotorrox:
Does this Eutrotorrox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
0) None of the above?
1 = Petroferric Eutrotorrox
2 = Lithic Eutrotorrox
0 = Typic Eutrotorrox

Haplotorrox:
Does this Haplotorrox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
0) None of the above?
1 = Petroferric Haplotorrox
2 = Lithic Haplotorrox
0 = Typic Haplotorrox

Akrustox:
Does this Akrustox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) Mottles of 4 or more value and 2 or less chroma within 1.25 m of the soil surface?
4) More than 5 percent plinthite in some horizon within 1.25 m?
5) A mollic or an umbric epipedon?
6) A color hue of 2.5YR or redder with moist values of less than 4 in most of the 25-100 cm depth?
7) A color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25-100 cm depth?
0) None of the above?
1 = Petroferric Akrustox
1 and 5 = Petroferric Akrustox
2 = Lithic Akrustox
3 = Aquic Akrustox
4 = Plinthic Akrustox
5 = Humic Akrustox
6 = Rhodic Akrustox
7 = Xanthic Akrustox
0 = Typic Akrustox

Eutrustox:
Does this Eutrustox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) Mottles of 4 or more value moist and 2 or less chroma within 1.25 m of the surface?
4) More than 5 percent plinthite in some horizon within 1.25 m?
5) A mollic or an umbric epipedon?
6) A color hue of 2.5YR or redder with moist values of less than 4 in most of the 25-100 cm depth?
7) A color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25-100 cm depth?
8) More than 40 percent clay in the surface 18 cm after mixing and the top of the kandic horizon within 1.5 m?
0) None of the above?
1 = Petroferric Eutrustox
2 = Lithic Eutrustox
3 = Aquic Eutrustox
4 = Plinthic Eutrustox
5 = Humic Eutrustox
6 = Rhodic Eutrustox
7 = Xanthic Eutrustox
8 = Alfic Eutrustox
6 and 8 = Rhodustalfic Eutrustox
0 = Typic Eutrustox

Kurustox:
Does this Kurustox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) Mottles of 4 or more value moist and 2 or less chroma within 1.25 m of the soil surface?
4) More than 5 percent plinthite in some horizon within 1.25 m?
5) A mollic or an umbric epipedon?
6) A color hue of 2.5YR or redder with moist values of less than 4 in most of the 25-100 cm depth?
7) A color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25-100 cm depth?
0) None of the above?
1 = Petroferric Kurustox
2 = Lithic Kurustox
3 = Aquic Kurustox
4 = Plinthic Kurustox
5 = Humic Kurustox
6 = Rhodic Kurustox
7 = Xanthic Kurustox
5 and 6 = Humic Rhodic Kurustox
0 = Typic Kurustox

Haplustox:
Does this Haplustox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) Mottles of 4 or more value moist and 2 or less chroma within 1.25 m of the surface?
4) More than 5 percent plinthite in some horizon above 1.25 m of the soil surface?
5) A mollic or an umbric epipedon?
6) A color hue of 2.5YR or redder with moist values of less than 4 in most of the 25-100 cm depth?
7) A color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25-100 cm depth?
0) None of the above?
1 = Petroferric Haplustox

2 = Lithic Haplustox
3 = Aquic Haplustox
4 = Plinthic Haplustox
5 = Humic Haplustox
6 = Rhodic Haplustox
7 = Xanthic Haplustox
0 = Typic Haplustox

Akroperox:
Does this Akroperox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) Mottles of 4 or more value and 2 or less chroma within 1.25 m of the soil surface?
4) More than 5 percent plinthite in some horizon above 1.25 m?
5) A mollic or an umbric epipedon?
6) A color hue of 2.5YR or redder with moist values of less than 4 in most of the 25-100 cm depth?
7) A color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25-100 cm depth?
0) None of the above?
1 = Petroferric Akroperox
2 = Lithic Akroperox
3 = Aquic Akroperox
4 = Plinthic Akroperox
5 = Humic Akroperox
6 = Rhodic Akroperox
7 = Xanthic Akroperox
0 = Typic Akroperox

Eutroperox:
Does this Eutroperox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact with 1.25 m of the soil surface?
3) Mottles of 4 or more value and 2 or less chroma within 1.25 m of the surface?
4) More than 5 percent plinthite in some horizon above 1.25 m of the surface?
5) A mollic or an umbric epipedon?
6) A color hue of 2.5YR or redder with moist values of less than 4 in most of the 25-100 cm depth?
7) A color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25-100 cm depth?
8) More than 40 percent clay in the surface 18 cm after mixing and the top of the kandic horizon within 1.5 m?
0) None of the above?
1 = Petroferric Eutroperox
2 = Lithic Eutroperox
3 = Aquic Eutroperox
4 = Plinthic Eutroperox
5 = Humic Eutroperox
6 = Rhodic Eutroperox
7 = Xanthic Eutroperox
8 = Alfic Eutroperox
6 and 8 = Rhodualfic Eutroperox
0 = Typic Eutroperox

Kuriperox:
Does this Kuriperox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?

3) Mottles of 4 or more value moist and 2 or less chroma within 1.25 m of the soil surface?
4) More than 5 percent plinthite in some horizon within 1.25 m?
5) A mollic or an umbric epipedon?
6) A color hue of 2.5YR or redder with moist values of less than 4 in most of the 25-100 cm depth?
7) A color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25-100 cm depth?
8) An 18 cm or thicker layer in the upper 75 cm with a bulk density less than 1 g/cc and either an acid-oxalate Al content More than 1 percent or 4*M* KOH-extractable Al of 0.75 percent or more?
0) None of the above?
1 = Petroferric Kuriperox
2 = Lithic Kuriperox
3 = Aquic Kuriperox
4 = Plinthic Kuriperox
5 = Humic Kuriperox
6 = Rhodic Kuriperox
5 and 6 = Humic Rhodic Kuriperox
7 = Xanthic Kuriperox
8 = Andic Kuriperox
6 and 8 = Andic Kuriperox
0 = Typic Kuriperox

Haploperox:
Does this Haploperox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) Mottles of 4 or more value and 2 or less chroma within 1.25 m of the soil surface?
4) More than 5 percent plinthite in some horizon above 1.25 m?
5) A mollic or an umbric epipedon?
6) A color hue of 2.5YR or redder with moist values of less than 4 in most of the 25-100 cm depth?
7) A color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25-100 cm depth?
8) An 18 cm or thicker layer in the upper 75 cm with a bulk density less than 1 g/cc and either an acid-oxalate extractable Al content of more than 1 percent or a 4*M* KOH-extractable Al content of 0.75 percent or more?
0) None of the above?
1 = Petroferric Haploperox
2 = Lithic Haploperox
3 = Aquic Haploperox
4 = Plinthic Haploperox
5 = Humic Haploperox
6 = Rhodic Haploperox
7 = Xanthic Haploperox
8 = Andic Haploperox
0 = Typic Haploperox
5 and 6 = Humic Rhodic Haploperox
5 and 8 = Andic Haploperox
6 and 8 = Andic Haploperox
5, 7, and 8 = Andic Haploperox

Akrudox:
Does this Akrudox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) Mottles of 2 or less chroma within 1.25 m of the soil surface?
4) More than 5 percent plinthite in some horizon within 1.25 m of the soil surface?
5) A mollic or an umbric epipedon?

6) A color hue of 2.5YR or redder with moist values of less than 4 in most of the 25-100 cm depth?
7) A color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25-100 cm depth?
0) None of the above?
1 = Petroferric Akrudox
2 = Lithic Akrudox
3 = Aquic Akrudox
4 = Plinthic Akrudox
5 = Humic Akrudox
6 = Rhodic Akrudox
7 = Xanthic Akrudox
2 and 6 = Lithic Akrudox
2 and 7 = Lithic Akrudox
3 and 4 = Plinthic Akrudox
3 and 5 = Aquic Akrudox
3 and 7 = Aquic Akrudox
5 and 6 = Humic Rhodic Akrudox
0 = Typic Akrudox

Eutrudox:
Does this Eutrudox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) Mottles of 2 or less chroma within 1.25 m of the soil surface?
4) More than 5 percent plinthite in some horizon within 1.25 m?
5) A mollic or an umbric epipedon?
6) A color hue of 2.5YR or redder with moist values less than 4 in most of the 25-100 cm depth?
7) A color hue of 7.5YR or yellower with values of 6 or more in most of the 25-100 cm depth?
8) More than 40 percent clay in the surface 18 cm after mixing and the top of the kandic horizon within 1.5 m depth?
0) None of the above?
1 = Petroferric Eutrudox
2 = Lithic Eutrudox
3 = Aquic Eutrudox
4 = Plinthic Eutrudox
5 = Humic Eutrudox
6 = Rhodic Eutrudox
7 = Xanthic Eutrudox
8 = Alfic Eutrudox
2 and 6 = Lithic Eutrudox
2 and 7 = Lithic Eutrudox
3 and 4 = Aquic Eutrudox
3 and 5 = Aquic Eutrudox
3 and 7 = Aquic Eutrudox
6 and 8 = Rhodudalfic Eutrudox
0 = Typic Eutrudox

Kurudox:
Does this Kurudox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) Mottles of 4 or more value and 2 or less chroma within 1.25 m of the soil surface?
4) More than 5 percent plinthite in some horizon above 1.25 m?
5) A mollic or an umbric epipedon?
6) A color hue of 2.5YR or redder with moist values less than 4 in most of the 25-100 cm depth?

7) A color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25-100 cm depth?
8) An 18 cm or thicker layer in the upper 75 cm with a bulk density less than 1 g/cc and either an acid-oxalate Al content more than 1 percent or 4*M* KOH-extractable Al of 0.75 percent or more?
0) None of the above?
1 = Petroferric Kurudox
2 = Lithic Kurudox
3 = Aquic Kurudox
4 = Plinthic Kurudox
5 = Humic Kurudox
6 = Rhodic Kurudox
7 = Xanthic Kurudox
5 and 6 = Humic Rhodic Kurudox
6 and 8 = Andic Kurudox
8 = Andic Kurudox
0 = Typic Kurudox

Hapludox:
Does this Hapludox have:
1) Petroferric contact within 1.25 m of the soil surface?
2) Lithic contact within 1.25 m of the soil surface?
3) Mottles of 4 or more value and 2 or less chroma within 1.25 m of the soil surface?
4) More than 5 percent plinthite in some horizon above 1.25 m?
5) A mollic or an umbric epipedon?
6) A color hue of 2.5YR or redder with moist values less than 4 in most of the 25-100 cm depth?
7) A color hue of 7.5YR or yellower with values of 6 or more in most of the 25-100 cm depth?
8) An 18 cm or thicker layer in the upper 75 cm with a bulk density less than 1 g/cc and either an acid oxalate-extractable Al content or more than 1 percent or a 4*M* KOH-extractable Al content of 0.75 percent or more?
0) None of the above?
1 = Petroferric Hapludox
2 = Lithic Hapludox
3 = Aquic Hapludox
4 = Plinthic Hapludox
5 = Humic Hapludox
6 = Rhodic Hapludox
7 = Xanthic Hapludox
8 = Andic Hapludox
5 and 6 = Humic Rhodic Hapludox
5 and 8 = Andic Hapludox
5, 6, and 8 = Andic Hapludox
6 and 8 = Andic Hapludox
0 = Typic Hapludox

Particle-size Classes
Weighted average clay content between 25 cm and 1 m or lithic, petroferric, or paralithic contact, whichever is shallower.
1) Less than 18 percent clay.
2) 18 to 34 percent clay.
3) 35 to 59 percent clay.
4) 60 percent or more clay

(If 35 percent or more rock fragments, add zero to above—i.e., 10, 20, etc.)

1 = coarse-loamy	10 = loamy skeletal
2 = fine-loamy	20 = loamy skeletal
3 = fine	30 = clayey skeletal
4 = very fine	40 = clayey skeletal

Mineralogy Classes (mineralogy control sections)

1) More than 40 percent iron oxide (28 percent Fe) by sulfuric acid or 32 percent iron oxide (22.4 percent Fe) by dithionite citrate.
2) 18-40 percent iron oxide (12.6-28 percent Fe) by sulfuric acid or 14-32 percent iron oxide (9.8-22.4 percent Fe) by dithionite citrate.
3) More than 25 percent gibbsite on a whole soil, including gravel, basis.
4) More than 50 percent of the clay (less than 0.002 mm) halloysite.
5) More than 2 meq KCl-extractable Al/100 g soil less than 2 mm in some 30 cm layer of the mineralogy control section.
0) None of the above.

1 = Ferruginous
2 = Ferritic
3 = Gibbsitic
4 = Halloysitic
5 = Allic
0 = Kaolinitic
1 and 3 = Ferruginous-Gibbsitic
1 and 5 = Ferruginous-Allic
3 and 5 = Gibbsitic-Allic
2 and 3 = Ferritic-Gibbsitic
2 and 5 = Ferritic-Allic

Soil Temperature Classes

Soil temperature classes are determined as a mean annual temperature at a 50-cm depth (select one of below):

1) Mean annual soil temperature of 22°C or higher
2) Mean annual soil temperature between 15 and 22°C
3) Mean annual soil temperature between 8 and 15°C
   If the average soil temperature for June, July, and August is 5°C or more different from that in December, January, and February add 0 to the above (i.e., 10, 20, or 30).

1 = isohyperthermic	10 = hyperthermic
2 = isothermic	20 = thermic
3 = isomesic	30 = mesic

Circular Letter No. 17, July 1986

Circular Letter No. 17 was the final duty of ICOMOX as an international committee formulated under the mandate of the USDA-Soil Conservation Service in its role as lead organization in the National Cooperative Soil Survey. Although all committee members were encouraged to respond to this letter, their responses were forwarded to the SCS for consideration as the ICOMOX proposal for further editing by the Soil Survey Staff for publication as an approved amendment to Soil Taxonomy. Circular Letter No. 17 is reproduced *in toto*.

International Committee on Classification of Oxisols ICOMOX

Circular Letter No. 17 July 1986

TO:

FROM: S. W. Buol
Soil Science Department
Box 7619
North Carolina State University
Raleigh, North Carolina 27695-7619 USA

1. Introduction

First, I want to thank all of you for your personal cooperation and sincere dedication to restructuring the classification of Oxisols in Soil Taxonomy. An additional thanks to those of you who were on the Brazilian tour for the International Committee Workshop. I am certain all of you on that tour join me in appreciation to Dr. Marcello Camargo and his staff of EMBRAPA for the excellent preparations and conduct of the tour. There is no doubt that without EMBRAPA and its excellent staff scientists, the world would not be able to attain the understanding of soils in the intertropical world nearly as well as we do today. We all wish them well and hope that they will be able to visit each of us, and we them. They certainly set a standard for scientific excellence that will be a role model for future studies in soil science.

This Circular Letter will probably be the final one from ICOMOX for some time. Enclosed is a draft of the ICOMOX proposal that will be sent for further testing. This testing period will be for 1 year and then a final draft will be prepared as an approved amendment to Soil Taxonomy. This, of course, is the function of the USDA-Soil Conservation Service, which is charged with the obligation to classify soils in Soil Taxonomy.

2. Objectives of Circular Letter No. 17

As I'm sure we were all aware, there was not enough time to work out all the fine points of the ICOMOX proposal at the meeting in Brazil. Thus, I have tried to incorporate all the changes from Circular Letter No. 16 that were discussed throughout the trip and at the final session in Brasília. Most of these will be evident by comparing the enclosed key with the one in Circular Letter No. 16. I wish to itemize those points that may differ from the majority opinion expressed at Brasília, and explain my reasons for not adhering to the opinions expressed at that time.

I would like to call your attention to the three items of major concern in this Circular Letter:

A) The ICOMOX Key (Draft, Proposal, 1986): Suggestions for testing are contained in item (6) of this letter.
B) Oxisols: This is a brief description of Oxisols for the layman.
C) Oxic horizon: This is intended to replace the oxic horizon pages 36-41 in Soil Taxonomy.

If, in your opinion, the key, the Oxisol, and/or the oxic horizon discussions are flawed, please submit your reasons and data to either Dr. Witty, Dr. Eswaran, and/or myself in the next few months (before February 1987) before the proposal goes for its final testing.

3. Placement Changes of Brazilian Pedons as a Result of the New Key (Table 1)

Discussion of key changes

a) The most obvious is the spelling change of Akr to Acr.
b) The family revision eliminated the dual mineral placement and reversed the ferritic-ferruginous names to fit the rest of Soil Taxonomy. (i.e., ferritic = greater than 40 percent Fe_2O_3 and ferruginous = 18-40 percent Fe_2O_3).
   Allitic was added if there was 10-25 percent gibbsite in the fine earth and not ferruginous or ferritic.
   Sesquic replaced the ferritic-gibbsitic and ferruginous-gibbsitic families.
   Allic was made a reaction class and is inserted between mineral class and temperature class in the family name.
c) Eutric subgroups were provided for "Acr" great groups (with or without color or epipedon exclusions).
d) Inceptic subgroups were provided in "Eutro" and "Hapl" great groups but were not seen on the trip.
e) Sloping families were provided for Aquox suborders. Sloping follows temperature class in the family name. An 8 percent limit was set and none of the examples on the trip were that steep.
f) The addition of "and a pH value (1*N* KCl) of 5 or more" to the "Acr" (less than 1.5 meq ECEC) criterion removes the kaolinite-dominated soils from "Acr" great groups, more clearly associating them with the "Hapl" great groups.

4. The "Hum" Proposal

The group at Brasília favored the establishment of "Hum" great groups (Humustox, Humudox, and Humiperox) to be given priority as the first great group in the respective keys. The criterion was suggested as "more than 16 kg O.C. per m^2 to a depth of 1 m with or without a mollic or an umbric epipedon."

After I returned, I tried this suggestion on all the well-drained profiles from the tour and some additional pedons from Africa. I went through the pedons using the proposed "Hum" great groups, with appropriate subgroups for Acric, Eutric, Kuric, Humic, Sombric, Xanthic, Rhodic, Plinthic, Aquic, Lithic, and Petroferric subgroups (Acric and Eutric would be suggested because their criteria then follow the "Hum" subgroups in the Key). I found that it was mainly the very-fine families that grouped into the new "Hum" great groups. I then plotted the kg of O.C. in each pedon (1 m^2 to a depth of 1 m) against the percent clay in that same depth. With the exception of pedon 2, the data formed a good relationship with texture. The 16 kg O.C. per m^2 to a depth of 1 m approximated 50 percent clay (i.e., those with more than 16 kg O.C. per m^2 to a depth of 1 m had more than 50 percent clay and those with less than 16 kg O.C. had less than 50 percent clay).

Table 1. Tour Pedons

Placement before Tour	Placement after Tour (ICOMOX 17) (Same = No Change from Tour)
1) Humic Akrudox; fine, kaol., isothermic	Humic Hapludox; fine, kaol., isothermic
2) Humic Akrudox; v-fine, allic, isothermic	Humic Haplodox; v-fine, kaol., (allic), isothermic
3) Rhodic Haplodox; fine-loamy, kaol., isohyperthermic	(same)
4) Rhodic Akrudox; v-fine, kaol., isohyperthermic	Rhodic Hapludox; v-fine, kaol, isohyperthermic
5) Typic Akrudox; v-fine, kaol., isohyperthermic	Typic Hapludox; v-fine, kaol., isohyperthermic
6) Typic Eutrodox; v-fine, kaol., isohyperthermic	(same)
7) Humic Rhodic Akrudox; v-fine, ferritic-gibbsitic, isohyperthermic	Humic Rhodic Acrudox; v-fine, sesquic, isohyperthermic
8) Rhodic Eutrodox; v-fine, ferritic, isohyperthermic	Rhodic Eutrodox; v-fine, ferruginous, isohyperthermic
9) Humic Akrudox; fine, kaol., isohyperthermic	Humic Acrudox; fine, allitic, isohyperthermic
10) Typic Akrudox; fine-loamy, kaol., isohyperthermic	Typic Acrudox; fine-loamy, kaol., isohyperthermic
11) Typic Akrudox; v-fine, ferritic-gibbsitic, isothermic	Typic Acrudox; v-fine, sesquic, isohyperthermic
12) Plinthic Akraquox; v-fine, gibbsitic, isohyperthermic	Plinthic Acraquox; v-fine, gibbsitic, isohyperthermic
13) Typic Haplustox; coarse-loamy, kaol, isohyperthermic	(same)
14) Humic Rhodic Eutrustox; v-fine ferritic, isohyperthermic	Humic Rhodic Eutrustox; v-fine, ferruginous, isohyperthermic
15) Typic Eutrustox; fine, kaol., isohyperthermic	(same)
16) Ustic Kandihumult; clayey, kaol., isohyperthermic	(same)
17) Humic Rhodic Akrustox; fine, kaol., isohyperthermic	Eutric Acrustox; fine, allitic, isohyperthermic
18) Typic Akrustox; v-fine, gibbsitic, isohyperthermic	Typic Acrustox, v-fine, gibbsitic, isohyperthermic
19) Humic Akrustox; clayey-skeletal, ferritic isohyperthermic	Humic Acrustox; clayey-skeletal, ferruginous, isohyperthermic
20) Typic Akrustox; v-fine, gibbsitic, isohyperthermic	Typic Acrustox; v-fine, gibbsitic, isohyperthermic
21) Typic Akrustox; v-fine, gibbsitic, isohyperthermic	Typic Acrustox; v-fine, gibbsitic, isohyperthermic
22) Rhodic Haplustox; fine, kaol., isohyperthermic	(same)
23) Aeric Ochraquox; fine, kaol, isohyperthermic	(same)

A ratio of kg O.C. per percent clay is nearly constant for all but pedon 2 on the trip. From this I conclude that there is about the same amount of organic carbon per unit of clay in all the well-drained Oxisols in my data set. Therefore, a proportional reduction in O.C. due to oxidation upon cultivation would have equal effect on ZPNC in all samples, defeating the rationale for "Hum" great groups. The best data I have indicates that upon cultivation a percentage reduction can be expected in such soils. Lepsch, Silva and Espironelo in Bragantia (1982) showed that after several years of cultivation the O.C. level under sugarcane was very dependent on clay content. For the above reasons, I have not incorporated the "Hum" great groups in the ICOMOX proposal.

5. Formation of Subgroups

The rules for naming subgroups are stated in Chapter 6 (p. 83-90) of Soil Taxonomy. I have tried to follow them in the subgroups I have named but may have made some mistakes. What is not covered is when to include more than one criterion listed under great groups as acceptable in a subgroup. For example, if there is a high base saturation in an Acrustox, it probably matters little if it is Humic or Rhodic, but I don't know. Thus, 8 with or without 5 or 6 (see Acrustox in Key).

We did not formally discuss this in Brazil, but from the informal discussions I had, I have tended to form Humic Rhodic as a common double subgroup. No doubt the handling of "implied" subgroups will be a continuing process in Oxisols as it is in the other orders. To date I have avoided the formation of dual

and "with or without" subgroups unless I had pedon data that required I make such decisions. (See pedon 17 of the tour.)

The standard used for the other orders in Soil Taxonomy relates to requirements for a certain number of pedons to the described and a certain number of hectares to be mapped in detail mapping before a subgroup is named. we also avoid establishing a subgroup for only one series or one family. Of course, this becomes a difficult standard to apply to Oxisols where only a small fraction of the area occupied by Oxisols is being mapped at detailed soil survey scale.

With this difficulty in mind, the proposal includes the names of many more subgroups than could be justified from the data reviewed in preparing the proposal. Ideally this should come after series have been established and detailed mapping done, but I have attempted to provide for those that experience, and fleeting observations from a moving bus, indicate are pedons in the landscape.

However, there exists a great body of characterized and described pedons from the many small-scale surveys that have been carried out in Oxisols. If these data could be studied and keyed in the ICOMOX proposal, it would greatly strengthen and improve the subgroup structure of the proposal. If the Oxisol data were assembled within the taxonomic structure of ICOMOX, and published, it would add greatly to our understanding of both Oxisol genesis and the transfer of information about the management of Oxisols among South America, Africa, Asia, and Australia. (Oh yes, Hawaii and Puerto Rico also.)

Perhaps one of you knows of a person in need of a sabbatical leave or someone to finance such an examination of the Oxisol data. (Better yet, both a person and the money.)

6. Suggestions for Testing the ICOMOX Proposal

I would suggest that pages 8-9 (The Attributes Desired) of Soil Taxonomy serve as guidelines for testing the ICOMOX Working Key. If you haven't done so recently, a rereading of that section would be worthwhile.

a. The first test should be one of the clarity of definitions. To test this it is best to have a number of qualified soil scientists independently classify pedon data and descriptions. Note any difficulty in the wording of the criteria definitions and suggest desirable changes.

b. Next, one should test the usability of the criteria. Here I refer to the discussion on p. 8 of Soil Taxonomy (fourth item under The Attributes Desired). Does the criterion require more data than you can reasonably be able to demand from present and future soil surveys? (It appears useless to argue that recent technology cannot be used as criteria just to recover old data, but it is not good to establish criteria on too few experiences or measurements available only with great difficulty.) Suggest new methods that may correlate with proposed criteria, perhaps as alternative limits.

c. Do the groupings created allow you and other users of the soil to make meaningful and quantitative statements comparing one group to another? For example, one could probably say that Torrox require irrigation for almost any type of crop cultivation, whereas Perox seldom need irrigation and crop damage from rot often occurs unless drying facilities are available locally. (Information that land-use planners may find useful.)

Although it is in our nature as soil scientists to try to fit taxonomic criteria to geographic distribution, and we should continue to try, it is unlikely that any taxonomic limit set to fit one area will not separate geographic associations in another part of the world. Using taxonomic names to help define mapping units is a mapping problem but often observations of problems are useful.

d. Remember that in this proposal we are using only five of the six categories in Soil Taxonomy. It is not possible to do justice to the Oxisols, with all their local variations, in five categories when the other orders use six. The series category is the "proving ground" for future improvements in Soil Taxonomy.

I believe the rules for defining series are quite simple:

(1) Series limits must not exceed limits of higher taxa. Simply, the series must be in only one family by definition.
(2) The criteria used must be observable and/or measurable within the pedon.
(3) There is no need to feel that series criteria are any less significant to soil use than criteria at higher categories. In fact, it may be of much greater significance at a local level than many of the higher categories. As a personal note, I feel the development of criteria at the series level is where the

individual soil scientist can make the greatest contribution to soil science. If the family groupings created in this proposal do not separate soils that are significantly different in your area, develop two series in each of the families in question and test the significance of that separation. Then, by all means, communicate your findings to others so they can test your criteria; and, who knows, what you find may someday become subgroup or great group criteria if determined to be of value by others.

(4) It is probably not necessary for me to write this but, as I am sure you are all aware, series as used as a category in Soil Taxonomy are not the "series" as used for a map unit name in detailed soil surveys. It is unfortunate that the same word is used for two such contrasting meanings, but such are the lessons of experience. Series in Soil Taxonomy are quantitatively defined concepts of a limited range of soil properties. It has no geographic limit as a taxonomic unit but only when the "name" of the series is used to identify a geographically delinated map unit on a soil map.

7. Future

All of your responses must be in to Dr. Eswaran, Dr. Witty, or me by February 28, 1987. A final proposal draft will then be prepared for wider circulation.

An old saying in this part of the U.S. goes "If the good Lord willing and the creeks don't rise," I will continue to work with the revision of the ICOMOX proposal. It is improbable that I will generate another circular letter unless others feel the need to solicit your collective opinion. No doubt correspondence will continue on a personal basis as we attempt to improve our classification of Oxisols.

My personal thanks to each of you.

ICOMOX Working Key Revision

Great Group Keys

Acraquox:
Does this Acraquox have:
1) An orchric epipedon?
2) More than 5 percent plinthite in some horizon within 125 cm of the soil surface?
0) None of the above?
1 = Ochric Acraquox
2 = Plinthic Acraquox
0 = Typic Acraquox

Plinthaquox:
Does this Plinthaquox have:
1) An ochric epipedon?
0) None of the above?
1 = Ochric Plinthaquox
2 = Typic Plinthaquox

Umbraquox:
Does this Umbraquox have:
1) Mottles with chromas of more than 2 in the horizon immediately below the epipedon?
2) More than 5 percent plinthite in some horizon within 125 cm of the soil surface?
3) Base saturation more than 35 percent (NH_4OAc) in all parts above 125 cm?
0) None of the above?
1 = Aeric Umbraquox
2 = Plinthic Umbraquox
3 = Eutric Umbraquox
0 = Typic Umbraquox

Ochraquox:
Does this Ochraquox have:
1) Mottles with chromas of more than 2 in the horizon immediately below the epipedon?
2) More than 5 percent plinthite in some horizon above 125 cm?
3) Base saturation more than 35 percent (NH_4OAc) in all parts above 125 cm?
0) None of the above?
1 = Aeric Ochraquox
2 = Plinthic Ochraquox
3 = Eutric Ochraquox
0 = Typic Ochraquox

Acritorrox:
Does this Acritorrox have:
1) Petroferric contact within 125 cm of the soil surface?
2) Lithic contact within 125 cm of the soil surface?
0) None of the above?
1 = Petroferric Acritorrox
2 = Lithic Acritorrox
0 = Typic Acritorrox

Eutrotorrox:
Does this Eutrotorrox have:
1) Petroferric contact within 125 cm of the soil surface?
2) Lithic contact within 125 cm of the soil surface?
0) None of the above?
1 = Petroferric Eutrotorrox
2 = Lithic Eutrotorrox
0 = Typic Eutrotorrox

Haplotorrox:
Does this Haplotorrox have:
1) Petroferric contact within 125 cm of the soil surface?
2) Lithic contact within 125 cm of the soil surface?
0) None of the above?
1 = Petroferric Haplotorrox
2 = Lithic Haplotorrox
0 = Typic Haplotorrox

Acrustox:
Does this Acrustox have:
1) Petroferric contact within 125 cm of the soil surface?
2) Lithic contact within 125 cm of the soil surface?
3) Mottles of 4 or more value moist and 2 or less chroma within 125 cm of the soil surface?
4) More than 5 percent plinthite in some horizon within 125 cm of the soil surface?
5) A mollic or an umbric epipedon?
6) A color hue of 2.5YR or redder with moist values of less than 4 in most of the 25-125 cm depth?
7) A color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25-125 cm depth?
8) More than 35 percent base saturation (NH_4OAc) in all parts to a depth of 125 cm?
0) None of the above?
1 with or without 5 = Petroferric Acrustox
2 = Lithic Acrustox
3 with or without 5 or 7 = Aquic Acrustox
4 = Plinthic Acrustox
5 = Humic Acrustox

5 and 6 = Humic Rhodic Acrustox
6 = Rhodic Acrustox
7 = Xanthic Acrustox
8 = with or without 5 or 6 = Eutric Acrustox
0 = Typic Acrustox

Eutrustox:
Does this Eutrustox have:
1) Petroferric contact within 125 cm of the soil surface?
2) Lithic contact within 125 cm of the soil surface?
3) Mottles of 4 or more value moist and 2 or less chroma within 125 cm of the soil surface?
4) More than 5 percent plinthite in some horizon within 125 cm of the soil surface?
5) A mollic or an umbric epipedon?
6) A color hue of 2.5YR or redder with moist values of less than 4 in most of the 25-125 cm depth?
7) A color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25-125 cm depth?
8) More than 40 percent clay in the surface 18 cm after mixing and the upper boundary of a kandic horizon above 150 cm?
9) More than 5 percent weatherable minerals in the sand fraction of some subhorizon above the 150 cm depth?
0) None of the above?
1 = Petroferric Eutrustox
2 = Lithic Eutrustox
3 with or without 5 or 7 = Aquic Eutrustox
4 = Plinthic Eutrustox
5 = Humic Eutrustox
5 and 6 = Humic Rhodic Eutrustox
6 = Rhodic Eutrustox
6 and 8 = Rhodustalfic Eutrustox
7 = Xanthic Eutrustox
8 = Kandustalfic Eutrustox
9 = Inceptic Eutrustox
0 = Typic Eutrustox

Kurustox:
Does this Kurustox have:
1) Petroferric contact within 125 cm of the soil surface?
2) Lithic contact within 125 cm of the soil surface?
3) Mottles of 4 or more value moist and 2 or less chroma within 125 cm of the soil surface?
4) More than 5 percent plinthite in some horizon within 125 cm of the soil surface?
5) A mollic or an umbric epipedon?
6) A color hue of 2.5YR or redder with moist values of less than 4 in most of the 25-125 cm depth?
7) A color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25-125 cm depth?
0) None of the above?
1 = Petroferric Kurustox
2 = Lithic Kurustox
3 with or without 5 or 7 = Aquic Kurustox
4 = Plinthic Kurustox
5 = Humic Kurustox
5 and 6 = Humic Rhodic Kurustox
6 = Rhodic Kurustox
7 = Xanthic Kurustox
0 = Typic Kurustox

Haplustox:
Does this Haplustox have:
1) Petroferric contact within 125 cm of the soil surface?
2) Lithic contact within 125 cm of the soil surface?
3) Mottles of 4 or more value moist and 2 or less chroma within 125 cm of the soil surface?
4) More than 5 percent plinthite in some horizon within 125 cm of the soil surface?
5) A mollic or an umbric epipedon?
6) A color hue of 2.5YR or redder with moist values of less than 4 in most of the 25-125 cm depth?
7) A color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25-125 cm depth?
8) More than 5 percent weatherable minerals in the sand fraction of some subhorizon above 150 cm?
0) None of the above?
1 = Petroferric Haplustox
2 = Lithic Haplustox
3 with or without 5 or 7 = Aquic Haplustox
4 = Plinthic Haplustox
5 = Humic Haplustox
5 and 6 = Humic Rhodic Haplustox
6 = Rhodic Haplustox
7 = Xanthic Haplustox
8 = Inceptic Haplustox
0 = Typic Haplustox

Acroperox:
Does this Acroperox have:
1) Petroferric contact within 125 cm of the soil surface?
2) Lithic contact within 125 cm of the soil surface?
3) Mottles of 4 or more value moist and 2 or less chroma within 125 cm of the soil surface?
4) More than 5 percent plinthite in some horizon within 125 cm of the soil surface?
5) A mollic or an umbric epipedon?
6) A color hue of 2.5YR or redder with moist values of less than 4 in most of the 25-125 cm depth?
7) A color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25-125 cm depth?
0) None of the above?
1 = Petroferric Acroperox
2 = Lithic Acroperox
3 with or without 5 or 7 = Aquic Acroperox
4 = Plinthic Acroperox
5 = Humic Acroperox
6 = Rhodic Acroperox
7 = Xanthic Acroperox
0 = Typic Acroperox

Eutroperox:
Does this Eutroperox have:
1) Petroferric contact within 125 cm of the soil surface?
2) Lithic contact within 125 cm of the soil surface?
3) Mottles of 4 or more value moist and 2 or less chroma within 125 cm of the soil surface?
4) More than 5 percent plinthite in some horizon within 125 cm of the soil surface?
5) A mollic or an umbric epipedon?
6) A color hue of 2.5YR or redder with moist values less than 4 in most of the 25-125 cm depth?
7) A color hue of 7.5YR or yellower with values of 6 or more in most of the 25-125 cm depth?
8) More than 40 percent clay in the surface 18 cm after mixing and the top of the kandic horizon within 150 cm?
0) None of the above?
1 = Petroferric Eutroperox

2 = Lithic Eutroperox
3 with or without 5 or 7 = Aquic Eutroperox
4 = Plinthic Eutroperox
5 = Humic Eutroperox
6 = Rhodic Eutroperox
6 and 8 = Rhodudalfic Eutroperox
7 = Xanthic Eutroperox
8 = Kandudalfic Eutroperox
0 = Typic Eutroperox

Kuriperox:
Does this Kuriperox have:
1) Petroferric contact within 125 cm of the soil surface?
2) Lithic contact within 125 cm of the soil surface?
3) Mottles of 4 or more value moist and 2 less chroma within 125 cm of the soil surface?
4) More than 5 percent plinthite in some horizon within 125 cm of the soil surface?
5) A mollic or an umbric epipedon?
6) A color hue of 2.5YR or redder with moist values less than 4 in most of the 25-125 cm depth?
7) A color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25-125 cm depth?
8) An 18 cm or thicker layer in the upper 75 cm with a bulk density less than 1 g/cc and either an acid oxalate-extractable Al content more than 1 percent or 4*M* KOH-extractable Al of 0.75 percent or more?
0) None of the above?
1 = Petroferric Kuriperox
2 = Lithic Kuriperox
3 with or without 5 or 7 = Aquic Kuriperox
4 = Plinthic Kuriperox
5 = Humic Kuriperox
5 and 6 = Humic Rhodic Kuriperox
6 = Rhodic Kuriperox
7 = Xanthic Kuriperox
8 with or without 6 = Andic Kuriperox
0 = Typic Kuriperox

Haploperox:
Does this Haploperox have:
1) Petroferric contact within 125 cm of the soil surface?
2) Lithic contact within 125 cm of the soil surface?
3) Mottles of 4 or more value moist and 2 or less chroma within 125 cm of the soil surface?
4) More than 5 percent plinthite in some horizon within 125 cm of the soil surface?
5) A mollic or an umbric epipedon?
6) A color hue or 2.5YR or redder with moist values less than 4 in most of the 25-125 cm depth?
7) A color hue of 7.5YR or yellower with values of 6 or more in most of the 25-125 cm depth?
8) An 18 cm or thicker layer in the upper 75 cm with a bulk density less than 1 g/cc and either an acid oxalate-extractable Al content of more than 1 percent or a 4*M* KOH extractable Al content of 0.75 percent or more?
9) More than 5 percent weatherable minerals in the sand fraction of some subhorizon above 150 cm?
0) None of the above?
1 = Petroferric Haploperox
2 = Lithic Haploperox
3 with or without 5 or 7 = Aquic Haploperox
4 = Plinthic Haploperox
5 = Humic Haploperox
5 and 6 = Humic Rhodic Haploperox
6 = Rhodic Haploperox

7 = Xanthic Haploperox
8 with or without 5, 6, or 7 = Andic Haploperox
9 = Inceptic Haploperox
0 = Typic Haploperox

Acrudox:
Does this Acrudox have:
1) Petroferric contact within 125 cm of the soil surface?
2) Lithic contact within 125 cm of the soil surface?
3) Mottles of 4 or more value moist and 2 or less chroma within 125 cm of the soil surface?
4) More than 5 percent plinthite in some horizon within 125 cm of the soil surface?
5) A mollic or an umbric epipedon?
6) A color hue of 2.5YR or redder with moist values less than 4 in most of the 25-125 cm depth?
7) A color hue of 7.5YR or yellower with values of 6 or more in most of the 25-125 cm depth?
8) More than 35 percent base saturation (NH_4OAc) in all parts to a depth of 125 cm?
0) None of the above?
1 = Petroferric Acrudox
2 with or without 6 or 7 = Lithic Acrudox
3 with or without 5 or 7 = Aquic Acrudox
4 with or without 3 = Plinthic Acrudox
5 = Humic Acrudox
5 and 6 = Humic Rhodic Acrudox
6 = Rhodic Acrudox
7 = Xanthic Acrudox
8 = Eutric Acrudox
0 = Typic Acrudox

Eutrudox:
Does this Eutrudox have:
1) Petroferric contact within 125 cm of the soil surface?
2) Lithic contact within 125 cm of the soil surface?
3) Mottles of 4 or more value moist and 2 or less chroma within 125 cm of the soil surface?
4) More than 5 percent plinthite in some horizon within 125 cm of the soil surface?
5) A mollic or an umbric epipedon?
6) A color hue of 2.5YR or redder with moist values less than 4 in most of the 25-125 cm depth?
7) A color hue of 7.5YR or yellower with values of 6 or more in most of the 25-125 cm depth?
8) More than 40 percent clay in the surface 18 cm after mixing and the top of a kandic horizon within 150 cm depth?
9) More than 5 percent weatherable minerals in the sand fraction of some subhorizon above 150 cm?
0) None of the above?
1 = Petroferric Eutrudox
2 with or without 6 or 7 = Lithic Eutrudox
3 with or without 5 or 7 = Aquic Eutrudox
4 = Plinthic Eutrudox
5 = Humic Eutrudox
6 = Rhodic Eutrudox
6 and 8 = Rhodudalfic Eutrudox
7 = Xanthic Eutrudox
8 = Alfic Eutrudox
9 = Inceptic Eutrudox
0 = Typic Eutrudox

Kurudox:

Does this Kurudox have:

1) Petroferric contact within 125 cm of the soil surface?
2) Lithic contact within 125 cm of the soil surface?
3) Mottles of 4 or more value moist and 2 or less chroma within 125 cm of the soil surface?
4) More than 5 percent plinthite in some horizon within 125 cm of the soil surface?
5) A mollic or an umbric epipedon?
6) A color hue of 2.5YR or redder with moist values less than 4 in most of the 25-125 cm depth?
7) A color hue of 7.5YR or yellower with values of 6 or more in most of the 25-125 cm depth?
8) An 18 cm or thicker layer in the upper 75 cm with a bulk density less than 1 g/cc and either an acid oxalate-extractable Al content of more than 1 percent or a 4*M* KOH-extractable Al content of 0.75 percent or more?
0) None of the above?

1 = Petroferric Kurudox
2 = Lithic Kurudox
3 with or without 5 or 7 = Aquic Kurudox
4 = Plinthic Kurudox
5 = Humic Kurudox
5 and 6 = Humic Rhodic Kurudox
6 = Rhodic Kurudox
7 = Xanthic Kurudox
8 with or without 6 = Andic Kurudox
0 = Typic Kurudox

Hapludox:

Does this Hapludox have:

1) Petroferric contact within 125 cm of the soil surface?
2) Lithic contact within 125 cm of the soil surface?
3) Mottles of 4 or more value moist and 2 or less chroma within 125 cm of the soil surface?
4) More than 5 percent plinthite in some horizon within 125 cm of the soil surface?
5) A mollic or an umbric epipedon?
6) A color hue of 2.5YR or redder with moist values less than 4 in most of the 25-125 cm depth?
7) A color hue of 7.5YR or yellower with values of 6 or more in most of the 25-125 cm depth?
8) An 18 cm or thicker layer in the upper 75 cm with a bulk density less than 1 g/cc and either an acid oxalate-extractable Al content of more than 1 percent or 4*M* KOH-extractable Al content of 0.75 percent or more?
9) More than 5 percent weatherable minerals in the sand fraction of some subhorizon above 150 cm?
0) None of the above?

1 = Petroferric Hapludox
2 = Lithic Hapludox
3 with or without 5 or 7 = Aquic Hapludox
4 = Plinthic Hapludox
5 = Humic Hapludox
5 and 6 = Humic Rhodic Hapludox
6 = Rhodic Hapludox
7 = Xanthic Hapludox
8 with or without 5 or 6 = Andic Hapludox
9 = Inceptic Hapludox
0 = Typic Hapludox

Particle-size Classes

Does the weighted average clay content between 25 and 100 cm, or lithic, petroferric, or paralithic contact, whichever is shallower, have:

1) Less than 18 percent clay?
2) 18 to 34 percent clay?
3) 35 to 59 percent clay?
4) 60 percent or more clay?

(If the control section contains more than 35 percent rock fragments, add zero to the above number, i.e., 10, 20, etc.)

1 = coarse-loamy	10 = loamy-skeletal
2 = fine-loamy	20 = loamy-skeletal
3 = fine	30 = clayey-skeletal
4 = very-fine	40 = clayey-skeletal

Mineralogy Classes

Does the mineralogy control section have:

1) More than 40 percent iron oxide (more than 28 percent Fe) by sulfuric acid or 32 percent by dithionite citrate (22.4 percent Fe)
2) 18-40 percent Fe_2O_3 (12.6-28 percent Fe) by sulfuric acid or 15-32 percent Fe_2O_3 (10.5-22.4 percent Fe) by dithionite citrate?
3) More than 40 percent gibbsite in the less than 2 mm fraction?
4) 10-25 percent gibbsite in the less than 2 mm fraction?
5) None of the above and more halloysite than kaolinite in the clay (less than 2 micron) fraction?

0) = None of the above?

1 = Ferritic
2 = Ferruginous
3 = Gibbsitic
3 with either 1 or 2 = Sesquic
4 = Allitic
5 = Halloysitic
0 = Kaolinitic

Soil Temperature Classes

Soil temperature classes are determined as a mean annual temperature at a 50 cm depth (select one from below).

1) Mean annual soil temperature of 22°C or higher.
2) Mean annual soil temperature between 15 and 22°C.
3) Mean annual soil temperature between 8 and 15°C.

(If the average soil temperature for June, July, and August is 5°C or more different from that in December, January, and February, add 0 to the above number (i.e., 10, 20, or 30.) (To approximate annual soil temperature amplitude, take the difference between mean summer and mean winter air temperatures and multiply by 0.66.)

1 = isohyperthermic	10 = hyperthermic
2 = isothermic	20 = thermic
3 = isomesic	30 = mesic

Soil Reaction Classes

Does this soil have more than 2 meq of KCl-extractable Al/100 g soil (fine earth fraction) in some 30 cm layer between 25-100 cm of the surface? (Y/N)

If yes Allic

Sloping Families (used in Aquox)

Does this Aquox have a slope greater than 8 percent?

If yes Sloping

Oxisols

Oxisols are reddish, yellowish, or greyish colored soils. They are most common on the gentle slopes of geologically old surfaces in tropical and subtropical regions. Their profiles are distinctive because of the lack of distinct horizons. Their surface horizons are usually somewhat darker in color than the subsoil, but the transition of subsoil features is gradual.

Oxisols consist mainly of quartz, kaolinite, oxides, and organic matter. Both the structure and "feel" of Oxisols are deceptive. Upon first examination they appear structureless and feel like a loamy particle size. While some are loamy or even coarser, many are extremely clayey, but that clay is aggregated in a strong grade of fine and very fine granular structure. To obtain a true "feel" of the fine texture, a wet sample must be worked for several minutes in the hands to break down the sandy-feeling, granular structure. The strong granular structure apparently causes most Oxisols to have a much more rapid permeability than would be predicted by the particle-size distribution class. Although compaction and reduction in permeability can be caused by cultivation, Oxisols are extremely resistant to compaction and so free draining that cultivation can take place soon after rain without puddling.

Oxisols are present in every soil moisture regime from aridic to perudic and aquic. Natural vegetation ranges from tropical rain forests to desert savannas. The lack of a unifying climatic factor throughout their geographic distribution indicates that their formation is genetically controlled by parent material parameters. As part of the definition, they are limited to very low cation-exchange capacities and weatherable mineral contents. They are present over many kinds of geologic bedrock but upon close examination, often to great depth, it is found that there is evidence that the material from which the pedons form has been transported. Where the material is not clearly transported, formation is most common in mafic rock.

Although many and perhaps most Oxisols are extremely infertile, there are many that have small but adequate supplies of nutrients and are immediately productive when cultivated. The reserves of plant nutrients even in the most fertile Oxisols are not great and, to sustain high yields, fertilizers and lime are needed after only a few years of cultivation. In most of the Oxisols, fertilizers are needed for even the first crop unless enough fertility is available for one or two crops from the ash derived upon burning the natural vegetation. Phosphorus is generally the most restrictive plant nutrient, mainly because of the tendency for the clay- and oxide-rich surface horizon to fix large amounts of fertilizer phosphorus in an unavailable form. However, once this capacity to fix the phosphate has been overcome by an initial application, there is no further fixation problem and annual fertilizer rates are no higher than for other soils. Because of the initial expense in fertilizing the Oxisols, they are cultivated extensively only where modern agronomic techniques are sustainable by an infrastructure of agrobusiness. In primative shifting cultivation, they are used only if they naturally support a large biomass to yield a large volume of ash upon burning.

Road building and other engineering practices are relatively easy in most Oxisols because of the physical stability of clay. There is little silt in most Oxisols, thus they have an extremely low available water holding capacity. Soil organic matter contents are usually much higher than indicated by the soil color. This may be due to the red color of the associated iron oxides. Frequently this organic matter is very stable, infertile humus, and slow to decompose.

The most extensive areas of Oxisols are on the interior plateaus of South America, the lower portion of the Amazon basin, significant portions of the central African basin, and important areas in Asia, Australia, and several tropical and subtropical islands.

Aquox

These are wet Oxisols. They are present in shallow depressions and as seepage areas at the base of slopes. Because the water table may seasonally fluctuate within the profiles, there is a tendency to accumulate iron in the form of secondary nodules, concretions, and plinthite. Most areas are small and little studied.

Acraquox

This great group is provided for those Aquox with extremely low cation-exchange capacities. Few examples have been made available for study.

Plinthaquox

This great group is provided for pedons of Aquox that have continuous plinthite within 125 cm of the surface. Only small areas of Plinthaquox have been observed and no data has been made available for study.

Umbraquox

These Aquox have dark-colored surface horizons over 25 cm thick. They may have either umbric or mollic epipedons. The reaction of the epipedon is often dependent on lime use in the area.

Ochraquox

These are Aquox with light-colored epipedons. Both high base saturation and low base status pedons are recognized.

Torrox

These are Oxisols of the arid regions. They frequently have a high base saturation and, when irrigated and fertilized, are excellent soils for a variety of crops. Their known occurrence is limited to Hawaii and perhaps some areas in Australia.

Acritorrox

This great group is provided for Torrox with very low cation-exchange values. No examples have been available for study.

Eutrotorrox

These high base saturated Torrox are best known in the Hawaiian Islands where they are used for irrigated crops.

Haplotorrox

This great group is provided for other Torrox that are low in base saturation percentage. No examples have been available for study.

Ustox

The Ustox are those Oxisols that are moist from natural rainfall in most years for at least 90 days, which is usually long enough for one rainfed crop, but not more than 270 days. Thus, crops are not grown continuously because there is inadequate moisture for at least 90 days in most years. Ustox may be the most extensive suborder occurring over a large portion of the interior of South America and in extensive areas of Africa. A few Ustox in areas of xeric soil moisture regime are found in Australia. The range of natural rainfall within the Ustox provides that two crops can be grown on some Ustox, while others are limited to only one crop unless supplemental irrigation is available.

Acrustox

These are Ustox with extremely low cation-exchange values. They can easily have their chemical environment altered by fertilizer and lime applications. Because of their low buffering capacity, it is desirable to use small but frequent applications of fertilizer and lime. Low content of exchangeable Al in the subsoil can be corrected by leaching basic cations from lime and fertilizer.

Eutrustox

These high base status Ustox are well known by local farmers because of their relatively high native fertility. In the past, they often supported natural forests, while surrounding areas of like rainfall but low base status supported savannas. It is rare to see forest vegetation today because the forests have been completely cut by native farmers. Why these Ustox have high saturation throughout their profile is not known, but they tend to occur over or near basic rocks such as limestone or basalt.

Kurustox

These Ustox have more than 40 percent clay in the surface 18 cm and an increase in clay content sufficient to meet the kandic horizon criteria below that depth. Most of these soils have been previously classified as Ultisols or Alfisols. The subsoil seldom contains evidence of translocated clay, but in some pedons they tend to have a weak to moderate grade of blocky structure in the subsoil, although there is usually a strong secondary structure that is fine granular.

Haplustox

These Ustox are present in dark red to yellow and all intervening colors. They represent vast areas in central South America and Africa.

Perox

This is a newly created suborder. Although the perudic soil moisture regime was defined as one in which precipitation equals or exceeds potential evapotranspiration every month of the year, the criterion was not used in Soil Taxonomy 1975. Perox are well-drained Oxisols with perudic soil moisture regimes. Clearing and burning is difficult because of atmospheric wetness. Also, it is difficult to cure many seed crops and storage of produce is difficult. There are no large areas of perudic soil moisture regime, but they appear distinctive enough to show and identify on some small-scale soil maps. If found useful, perhaps the concept should be considered in other orders.

Acroperox

These are well-drained Oxisols in the perudic soil moisture regime that have very low cation-exchange values.

Eutroperox

This great group is provided for Oxisols in the perudic soil moisture regime with high base saturation. No examples have been available for testing.

Kuriperox

These Oxisols with a perudic soil moisture regime have clay-textured surface horizons and a kandic subsurface horizon. Prior to this proposal, they would have been Paleudults. Subsoils often have weak to moderate grades of blocky structure. No pedons have been studied.

Haploperox

Only the presence of a perudic soil moisture regime distinguishes these Oxisols from the Udox. Their subsoils have granular structure and the epipedons may be either dark or light colored.

Oxic Horizon

The oxic horizon is intended to characterize a mineral subsurface horizon of sandy loam or finer particle size with low cation-exchange capacity and low weatherable mineral content. It is at least 30 cm (12 inches) thick. The clay-sized fraction is usually dominated by kaolinite with or without iron and aluminum oxhydrates and with few or no other lattice silicate minerals except hydroxy interlayered vermiculites. The silt and sand fraction of the oxic horizon is generally dominated by quartz with some other resistant minerals. Weatherable minerals, which are potential sources of plant nutrients (K, Ca, and Mg), may only be present if they do not exceed *10* percent of the *50-200* micron fraction. Rock fragments or lithorelicts may only be present if they are coated with sesquioxides or if the included weatherable minerals are completely altered.

A quantifiable cation-exchange capacity limit is placed on the clay-sized fraction. Where dispersion is a problem, 3x the percent water retained at 15-bar tension can be used to estimate clay content. The apparent CEC, by the 1*N* NH_4OAc pH 7 method is less than or equal to 16 meq/100 g clay, and the effective CEC (ECEC), as determined by the sum of NH_4OAc -displaced bases plus 1*N* KCl-extractable aluminum, is less than or equal to 12 meq/100 g clay. Since the determination of apparent clay CEC

values involves dividing the soil CEC by the percent clay content, these characteristics insure that soil materials with low-activity clay but with high organic-matter content are excluded. The mineralogy and charge characteristics also exclude horizons containing significant quantities of x-ray amorphous minerals. To further aid in limiting oxic horizons from andic materials, oxic horizons do not contain 1 percent or more acid oxalate-extractable aluminum plus one-half the acid oxalate-extractable iron. Some oxic-like horizons may have high amounts of low-charge illite, but these soils have more than the 10 percent muscovite in the 50-200 micron fraction and are thus excluded from oxic horizons on that criterion. This same criterion is expected to limit horizons containing much pyrophyllite, a mineral with practically no permanent charge, from oxic horizons.

The upper boundary of the oxic horizon is at 18 cm below the soil surface or the base of the Ap horizon or deeper when the mineralogical and charge characteristics meet the requirements of the oxic horizon. The clay content increase at the upper boundary has to be diffuse. The lower boundary is also defined by the mineralogical and charge requirements. In addition, the presence of saprolite that has rock structure morphology evident in a soil pit or a horizon may define the lower boundary of an oxic horizon.

Significance to Classification and Use

One important attribute of the oxic horizon is that it is almost devoid of primary weatherable minerals; thus, further weathering will release few plant nutrients.

Another important attribute is that in many soils with oxic horizons the clay content is relatively constant with depth, indicating little or no clay mobility. This suggests a high order of stability in the clay fraction, which has been attributed to cementation by sesquioxides. Oxic horizons usually have only traces of water-dispersible clay, if their net change is near zero, but this characteristic is also shared by some other horizons, so after years of testing it is not now deemed feasible to use this feature as a criterion.

A third attribute of most oxic horizons is the stable fine and very fine granular structure and thus the friable and porous nature of the horizon. Bulk densities are generally low, often near 1 g/cc in fine and very fine particle-size classes. Macrostructure may be angular or subangular blocky, but the grade of blocky structure is generally weak.

These and other attributes directly or indirectly influence the performance of soils containing oxic horizons. The very low cation-exchange capacity is an important consideration in soil management. In addition, some oxic horizons have a high capacity to adsorb and make some anions, especially phosphates, unavailable to plants. Large amounts of phosphate may need to be added as an initial amendment to overcome the fixation capacity. Cations may need to be added frequently and in small amounts to reduce leaching loss. The low CEC, where dominated by exchangeable Al, is often an advantage in that it only takes small amounts of basic cations to improve the base saturation percentage. Further, the ease of leaching basic cations makes the chemical deepening of the root zone feasible via continued lime or gypsum applications.

Although oxic horizons often contain high amounts of clay, their tendency to form a strong grade of very fine and fine granular structure may give them characteristics not unlike sands. They have low available water-holding capacities because most of the pores are either very large, between the granules, and thus do not retain water against the forces of gravity; or are very small, within the granules, and retain water at too great a tension for plants to extract. Plants may show moisture stress after only a week of rainless weather. Although the low available water-holding capacity is most limiting to shallow-rooted plants, yields of deep-rooted trees, such as rubber and oil palm, are also known to decline due to moisture stress.

It is considered desirable to identify soil horizons that are nearly mineralogically sterile from the standpoint of being able to supply basic cations from the continued weathering of primary minerals. As such, the oxic horizon can be considered a counterpart of the cambic horizon, which has a greater content of weatherable minerals. As with the cambic horizon, the exclusion of certain coarse particle-size classes is admittedly arbitrary, but in the case of the oxic horizon it is considered necessary to preserve the uniformity of the horizon to materials that have enough clay to reflect the low CEC nature and structural tendencies.

When considered in the vertical sequence of a soil profile, an increase in clay content with depth may be associated with increased grades of blocky structure not common to the central concept of the oxic horizon. Where the clay content increase underlies coarser particle-size surface horizons, a small increase in the amount of clay appears more significant to moisture relationships than when the surface horizon is clayey

in texture. This is especially true in the interpretation of soils that have been subjected to accelerated erosion. Where coarser textured surfaces erode in cultivated areas and finer textured subsoil material becomes incorporated into the plow layer, spatial heterogeneity with respect to plow layer characteristics develops. Thus, it is considered that this pattern is more closely related to soils that have argillic horizons than those that do not have rather abrupt increases in clay content with depth. Therefore, some horizons, with many oxic horizon properties such as low CEC and absences of weatherable minerals, will classify as kandic horizons and may be part of Ultisols and Alfisols rather than Oxisols.

The identification of an oxic horizon in most soils requires that the clay content increase with depth not exceed 1.2 times the clay content in the overlying horizons within a vertical distance of 15 cm (gradual boundary limit), which is the class limit for the kandic horizon when the surface horizon contains between 20 and 40 percent clay. If the surface horizon contains more than 40 percent clay, an oxic horizon must have less than an 8 percent absolute clay content increase within a 15-cm depth. If the surface horizon contains less than 20 percent clay, an oxic horizon must have an absolute clay content increase less than 4 percent in a vertical distance of 15 cm. This is admittedly an arbitrary limit, but one that lends itself to consistent identification in the field and rather easy verification by laboratory techniques.

Genesis

Oxic horizons are generally in soils of very old stable geomorphic surfaces. They may occur in soils on younger surfaces if the rock is easily weatherable, such as basalts or serpentinites, or if the material is pre-weathered. Oxic horizons are not common in soils on steep slopes where rejuvenation of the soil takes place through erosion, truncation, or lateral flow of base-enriched subsurface water.

Soils on old geomorphic surfaces, which may date to mid- or late-to end-Tertiary, have generally been reworked. Many of the surficial deposits are preweathered, transported over short distances, and deposited, perhaps several times. After deposition and stabilization of the landscape, weathering and soil formation starts anew. Stone lines composed of quartz or petroplinthite are common in some of these soils if the original material could supply the stones. Quartz veins may be traced through the saprolite but end abruptly or taper off at the stone line, indicating that the material above the stone line is allochthonous. Particle-size sorting may take place during transport and deposition and lithologic discontinuities are frequently present, although materials are very similar.

Earlier it was stated that the parent materials may be strongly preweathered. Post-depositional weathering continues, and the intensity is a function of the environmental conditions. In aridic climates, this is minimal, and it is supposed that the oxic properties were attained during previous, more humid phases of the climate, at more humid environments, or weathered in transport.

In more easily weatherable parent materials and when climatic conditions are favorable, oxic horizons form in soils on young surfaces and over a relatively short period. Leaching and desilicification are the most important processes, resulting in a deep sola. The weathering front moves rapidly down the soil and on many basic and ultrabasic rocks there is no real saprolitic zone as the oxic horizon rests on rock or on a thin weathering crust. Primary minerals are altered to kaolinite, and simultaneously or at a later stage, gibbsite and geothite also accumulate. Accidents of nature may occur, leaving behind some partially weathered rock or mineral fragments in the oxic horizon. These are generally rare and, if present, are frequently coated with sesquioxides. Pseudomorphs of olivine and augite may be present in some oxic horizons, but these are not considered indicators of lack of weathering.

Where located on stable surfaces, time has permitted the homogenization of the soil material by pedoturbation processes. It is also possible that the active pedoturbation has disrupted and assimilated any evidence of lessivage, such as clay skins. Consequently, most oxic horizons are uniform in color, texture, and other mineral-chemical properties to great depths in the soil. The pedoturbation processes have also disrupted any rock structure. In some saprolites, weathering results in a pseudomorphic alteration of feldspar phenocrysts to gibbsite, the aggregates of which retain the original fabric. Mineral-chemically, the saprolite may meet the requirements of an oxic horizon. The saprolite is not considered an oxic horizon if it retains more than 5 percent rock fabric and if the secondary minerals are pseudomorphs after the primary minerals. In this respect, booklets of kaolinite formed through the pseudomorphic alteration of biotite are considered weatherable minerals. In an oxic horizon, these are disrupted and assimilated in the soil material.

Soils with oxic horizons frequently occupy the upper part of the landscape. The silica potential is also very low in such soils, having a net leaching environment, so that there is no possibility for synthesis of 2:1 clay minerals. Even in the wet soils with oxic horizon, the recharging water may be so low in bases and silica, and despite the high water table, the soil is continuously flushed and leached.

Isohyperthermic soil temperature regimes and udic or perudic soil moisture regimes are often considered optimal for oxic horizon formation. However, soils with oxic horizons are very common in areas with ustic soil moisture regimes or with isothermic soil temperature regimes but are rare in areas with aridic soil moisture regimes and isomesic soil temperature regimes. Some oxic horizons are present in non-iso soil temperature regimes. Although paleoclimatic factors have been attributed to the formation of the latter kind of oxic horizons, parent material is probably a major contributor to their formation.

Summary of Oxic Horizon Properties

In summary, the oxic horizon is a subsurface horizon that:

1. Is at least 30 cm thick;
2. Has a particle size of sandy loam or finer in the fine earth fraction;
3. Has a fine earth fraction (less than 2 mm) that has an apparent ECEC (NH_4OAc bases plus 1*N* KCl-extractable Al/percent clay) less than or equal to 12 meq/100 g clay and has an apparent CEC 7 (NH_4OAc CEC/percent clay) of less than or equal to 16 meq/100 g clay (measured clay or 3x 15-bar water percentage);
4. Does not have as much as 10 percent weatherable minerals in the 50-200 micron faction;
5. Has a diffuse upper particle-size boundary (i.e., less than 1.2x clay content increase within a vertical distance of 15 cm if the surface horizon contains 15-40 percent clay; less than 3 percent absolute clay content increase if the surface contains less than or equal to 15 percent clay; less than 8 percent absolute if the surface contains equal to or greater than 40 percent clay);
6. Has less than 1 percent acid oxalate-extractable aluminum;
7. Has less than 5 percent by volume that shows rock structure unless the lithorelicts containing weatherable minerals are coated with sesquioxides;
8. Does not have soil material that contains greater than 85 percent gravel (including petroferric and petroplinthic material) by volume.

Approved Amendments to Soil Taxonomy
615.45 Oxisol Amendment

Introduction

In 1977 the Soil Conservation Service established the International Committee on Oxisols (ICOMOX) to review the classification of Oxisols and make recommendations for changes. The work of ICOMOX was partly based on the outcome of another committee, the International Committee on Low Activity Clays (ICOMLAC). The concept of the 'kandic horizon' was developed by ICOMLAC and, with this in place, ICOMOX could then define the oxic horizon and the classes of the Order.

The placement of soils with low activity clays (LAC) was a problem for many people working in the tropics. This relatively homogeneous group of soils was divided among several taxa in Soil Taxonomy. The presence of an argillic horizon was considered to be important and the definition of Oxisols excluded soils with argillic horizons. The performance of the LAC soils and many of their engineering properties, however, indicated their response was more similar to Oxisols than to Ultisols or Alfisols. After considerable testing, the concept of Oxisols was enlarged to include the LAC soils with more than 40% clay in the surface layers. This major conceptual change required revisions of the entire order of Oxisols. These revisions and corresponding changes in other taxa are presented in this amendment.

ICOMOX also considered other points of concern which users of Soil Taxonomy were encountering in the tropics. The concept of the Humox, the perudic soil moisture regime, the sombric horizon, plinthite, and the general structure of the taxa itself were tested. The data base of the National Soil Survey Laboratories proved very valuable for this purpose.

These amendments to Soil Taxonomy include the final proposal of ICOMOX. Those who have reviewed it agree that the result is a major and significant improvement to Soil Taxonomy; but there are still a few minor areas which will need attention as more information becomes available. It is only through applying the system that its weaknesses become apparent, which in turn, will bring about changes in the future.

The following page reference changes are required in Soil Taxonomy (Soil Survey Staff 1975) to accommodate these amendments.

Page 36, first column, Summary of properties, item 3. Change item 3 to read: "3. Minerals that consist of (a) enough amorphous or 2:1 lattice clay to give a cation-exchange capacity (by NH_4OAc) of more than 16 meq per 100 g clay or (b) ≥10 percent weatherable minerals;"

Page 36, second column, oxic horizon. Delete all discussion on oxic horizon through item 7 of the "summary of properties" on page 39 and replace with the following:

OXIC HORIZON

The oxic horizon is intended to characterize a mineral subsurface horizon of sandy loam or finer particle size with low cation exchange capacity and low weatherable mineral content. It is at least 30 cm (12 inches) thick. The clay sized fraction is usually dominated by kaolinite with or without iron and aluminum oxyhydrates and with few or no other lattice silicate minerals except hydroxy interlayered vermiculites.The silt and sand fraction of the oxic horizon is generally dominated by quartz with some other resistant minerals. Weatherable minerals, which are potential sources of plant nutrients (K, Ca, and Mg), may be present only if they do not exceed 10 percent of the *50-200* micron fraction. Rock fragments or lithorelicts

may be present only if they are coated with sesquioxides or if the included weatherable minerals are completely altered.

A quantifiable cation exchange capacity limit is placed on the clay-sized fraction. Where dispersion is a problem, 3 x the percent water retained at 15 bar tension is used to estimate clay content. The apparent CEC, by the 1*N* NH_4OAc pH 7 method is equal to or less than 16 meq per 100 g of clay, and the effective CEC (ECEC), as determined by the sum of NH_4OAc displaced bases plus 1*N* KCl extractable aluminum, is equal to or less than 12 meq per 100 g clay. Since the determination of apparent clay CEC values involves dividing the soil CEC by the percent clay content, these characteristics insure that soil materials with low-activity clay but with high organic-matter content are excluded. The mineralogy and charge characteristics also exclude horizons containing significant quantities of short-range order minerals.The oxic horizon does not have andic soil properties.[1] Some oxic-like horizons may have high amounts of low-charge illite, but they have more than 10 percent muscovite in the 50-200 micron fraction and are thus excluded from oxic horizons. This same criterion is expected to limit horizons containing much pyrophyllite, a mineral with practically no permanent charge, from oxic horizons.

The upper boundary of the oxic horizon is at 18 cm below the soil surface or the base of the Ap horizon, whichever is deeper, or at a deeper depth where the mineralogical and charge characteristics meet the requirements of the oxic horizon. Any increase in clay content at the upper boundary must be diffuse. The lower boundary is also defined by the mineralogical and charge requirements. In addition, the presence of saprolite that has rock structure may define the lower boundary of an oxic horizon.

Significance to soil classification and use

One important attribute of the oxic horizon is that it is almost devoid of primary weatherable minerals: thus, further weathering will release few plant nutrients.[2]

Another important attribute is that in many soils with oxic horizons the clay content is relatively constant with depth indicating little or no clay mobility. This suggests a high order of stability in the clay fraction, which has been attributed to cementation by sesquioxides. Oxic horizons usually have only traces of water-dispersible clay, if their net charge is near zero, but this characteristic is also shared by some other horizons.

A third attribute of most oxic horizons is the stable fine and very fine granular structure and thus the friable and porous nature of the horizon. Bulk densities are generally low, often near 1g/cm^3 in fine and very fine particle size classes. Macrostructure may be angular or subangular blocky, but the grade of blocky structure is generally weak.

These and other attributes directly or indirectly influence the performance of soils containing oxic horizons. The very low cation exchange capacity is an important consideration in soil management. In addition, some oxic horizons have a high capacity to adsorb anions and make some, especially phosphates, unavailable to plants. Large amounts of phosphate may need to be added as an initial amendment to

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[1] Andic soil properties are tentatively defined as soil materials meeting one or more of the following three requirements:

1. a. Acid oxalate-extractable aluminum plus 1/2 acid oxalate-extractable iron is 2.0 percent or more in the < 2 mm fraction;
   b. Bulk density of the < 2 mm fraction, measured at 1/3-bar water retention, is ≤ 0.90 g/cm^3; and
   c. Phosphate retention is more than 85 percent; or
2. a. More than 60 percent by volume of the whole soil is volcaniclastic material coarser than 2 mm; and
   b. Acid oxalate-extractable aluminum plus 1/2 acid oxalate-extractable iron is 0.40 percent or more in the < 2 mm fraction; or
3. The 0.02 to 2.0 mm fraction is at least 30 percent of the < 2 mm fraction and meets one of the following:
   a. If the < 2 mm fraction has acid oxalate-extractable aluminum plus 1/2 acid oxalate-extractable iron of 0.40 percent, there is at least 30 percent volcanic glass in the 0.02 to 2.0 mm fraction;
   b. If the < 2 mm fraction has acid oxalate-extractable aluminum plus 1/2 acid oxalate extractable iron of 2.0 percent or more, there is at least 5 percent volcanic glass in the 0.02 to 2.0 mm fraction; or
   c. If the < 2 mm fraction has acid oxalate-extractable aluminum plus 1/2 acid oxalate-extractable iron of between 0.40 percent and 2.0 percent, there is a proportional content of volcanic glass in the 0.02 to 2.0 mm fraction between 5 and 30 percent.

[2] The 10 percent weatherable limit approximates a reserve of only 25 meq Na^+, K^+, and Ca^{++}, Mg^{++} in the primary minerals. (Herbillon, personal communications).

overcome the fixation capacity. Cations may need to be added frequently and in small amounts to compensate for leaching loss. The low CEC, where dominated by exchangeable Al, is often an advantage in that it only takes small amounts of basic cations to increase the base saturation percentage. Further, the ease with which basic cations are leached makes the chemical deepening of the root zone feasible via continued lime or gypsum applications.

Although oxic horizons often contain high amounts of clay, their tendency to form a strong grade of very fine and fine granular structure may give them characteristics similar to sands. They have low available water-holding capacities because most of the pores are either very large, between the granules, and thus do not retain water against the forces of gravity; or are very small, within the granules, and retain water at too great a tension for plants to extract. Plants may show moisture stress after only a week without rain. Although the low available water-holding capacity is most limiting to shallow-rooted plants, yields of deep-rooted trees, such as rubber and oil-palm, are also known to decline due to moisture stress.

It is considered desirable to identify soil horizons that are nearly mineralogically sterile due to being unable to supply basic cations from the continued weathering of primary minerals. As such, the oxic horizon can be considered a counterpart of the cambic horizon which has a greater content of weatherable minerals. As with the cambic horizon, the exclusion of certain coarse particle-size classes is admittedly arbitrary, but in the case of the oxic horizon it is considered necessary to preserve the uniformity of the horizon with materials that have enough clay to reflect the low CEC nature and structural tendencies.

When considered in the vertical sequence of a soil profile, an increase in clay content with depth may be associated with increased grades of blocky structure not common to the central concept of the oxic horizon. Where the clay content increase underlies coarser particle-size surface horizons, a small increase in the amount of clay appears more significant to moisture relationships than when the surface horizon is clayey in texture. This is especially true in the interpretation of soils that have been subjected to accelerated erosion. Where coarser textured surfaces erode in cultivated areas and finer textured subsoil material becomes incorporated into the plow layer, spatial heterogeneity with respect to plow layer characteristics develops. Thus, it is considered that this pattern is more closely related to soils that have argillic horizons than those that do not have rather abrupt increases in clay content with depth. Therefore, some horizons, with many oxic horizon properties such as low CEC and absences of weatherable minerals, will classify as kandic horizons and may be part of Ultisols and Alfisols rather than Oxisols if there is less than 40 percent clay in the upper 18 cm.

The identification of an oxic horizon in most soils requires that the clay content increase with depth not exceed 1.2 times the clay content in the overlying horizons within a vertical distance of 15 cm (gradual boundary limit) if the surface horizon contains 20 percent to 40 percent clay. If the surface horizon contains more than 40 percent clay, an oxic horizon must have less than an 8 percent absolute clay content increase within a 15 cm depth. If the surface horizon contains less than 20 percent clay, an oxic horizon must have an absolute clay content increase less than 4 percent in a vertical distance of 15 cm.This is admittedly an arbitrary limit, but one that lends itself to consistent identification in the field and rather easy verification by laboratory techniques.

Genesis

Oxic horizons are generally in soils on very old stable geomorphic surfaces.They may occur in soils on younger surfaces if the parent rock is easily weatherable, such as basalts or serpentinites, or if the material is preweathered. Oxic horizons are not common in soils on steep slopes where rejuvenation of the soil takes place through erosion, truncation, or lateral flow of base-enriched subsurface water.

Soils on old geomorphic surfaces, which may date to mid- or late-Tertiary, have generally been reworked. Many of the surficial deposits are preweathered, transported over short distances, and deposited, perhaps several times. After deposition and stabilization of the landscape, weathering and soil formation starts anew. Stone lines composed of quartz or petroplinthite are common in some of these soils if the original material could supply the stones. Quartz veins may be traced through the saprolite but end abruptly or taper off at the stone line, indicating that the material above the stone line has been transported. Particle-size sorting may take place during transport and deposition and lithologic discontinuities are common, although materials are very similar.

Earlier it was stated that the parent materials may be strongly preweathered. Post-depositional weathering continues, and the intensity is a function of the environmental conditions. In aridic climates, this is minimal, and it is supposed that the oxic properties were attained during previous, more humid phases of the climate, in poorly drained environments, or weathered in transport.

In more easily weatherable parent materials and when climatic conditions are favorable, oxic horizons form in soils on young surfaces and over a relatively short period. Leaching and desilicification are the most important processes, resulting in a deep sola. The weathering front moves rapidly down the soil and on many basic and ultrabasic rocks there is no real saprolitic zone as the oxic horizon rests on rock or on a thin weathering crust. Primary minerals are altered to kaolinite, and simultaneously or at a later stage, gibbsite and geothite also accumulate. Accidents of nature may occur, leaving behind some partially weathered rock or mineral fragments in the oxic horizon. These are generally rare and if present are frequently coated with sesquioxides. Pseudomorphs of olivine and augite may be present in some oxic horizons, but these are not considered as indicators of lack of weathering.

On stable surfaces, time has permitted the homogenization of the soil material by pedoturbation processes. It is also possible that the active pedoturbation has disrupted and assimilated any evidence of lessivage, such as clay skins. Consequently, most oxic horizons are uniform in color, texture, and other mineralogic-chemical properties to great depths in the soil. The pedoturbation processes have also disrupted any rock structure. In some saprolites, weathering results in a pseudomorphic alteration of feldspar phenocrysts to gibbsite, the aggregates of which retain the original fabric. Mineralogically-chemically, the saprolite may meet the requirements of an oxic horizon, but is not considered an oxic horizon if it retains more than 5 percent rock fabric and if the secondary minerals are pseudomorphs after the primary minerals. In this respect, booklets of kaolinite formed through the pseudomorphic alteration of biotite are considered as weatherable minerals. In an oxic horizon, these are disrupted and assimilated in the soil material.

Soils with oxic horizons frequently occupy the upper part of the landscape. The silica potential is also very low in such soils, having a net leaching environment, so that there is no possibility for synthesis of 2:1 clay minerals. Even in the wet soils with oxic horizons, the recharging water may be so low in bases and silica, that despite the high water table, the soil is continuously flushed and leached.

Isohyperthermic soil temperature regimes and udic or perudic soil moisture regimes are often considered optimal for oxic horizon formation. However, soils with oxic horizons are common in areas with ustic soil moisture regimes or with isothermic soil temperature regimes but are rare in areas with aridic soil moisture regimes and isomesic soil temperature regimes. Some oxic horizons are present in non-iso soil temperature regimes and, although paleoclimatic factors have been attributed to their formation, parent material is also probably a major contributor.

Summary of oxic horizon properties

In summary, the oxic horizon is a subsurface horizon that:

1. Is at least 30 cm thick;
2. Has a particle-size of sandy loam or finer in the fine earth fraction;
3. Has a fine earth fraction (<2 mm) that has an apparent ECEC (NH_4OAc bases plus 1*N* KCl extractable Al) equal to or less than 12 meq per 100 g clay and has an apparent CEC pH 7 (NH_4OAc CEC) equal to or less than 16 meq/100 g clay (measured clay or 3 X 15 bar water, whichever is greater but less than 100);
4. Does not have as much as 10 percent weatherable minerals in the 50-200 micron faction;
5. Has a diffuse upper particle-size boundary (i.e., <1.2 times clay content increase within a vertical distance of 15 cm if the surface horizon contains 20-40 percent clay; less than 4 percent absolute clay content increase if the surface contains ≤20 percent clay; <8 percent absolute if the surface contains ≥40 percent clay);
6. Does not have andic soil properties[3],
7. Has less than 5 percent by volume that shows rock structure unless the lithorelicts containing weatherable minerals are coated with sesquioxides."

[3] See footnote 1.

Pages 36, 38, and 39. Delete footnotes 10, 11, 12, 13, 14, and 15.

Page 41, first column, line 14. Change ". . . 2.5 times 15-bar water. . . " to ". . . 3 times 15-bar water. . . "

Page 48, Lithic contact, second column. Change the last paragraph of this section to read: "A lithic contact is diagnostic at the subgroup level if it is within 125 cm of the soil surface of Oxisols and within 50 cm of the soil surface of all other mineral soils."

Page 56, first column, second paragraph, last sentence. Change to the following: "The formative element *per* is used in selected taxa."

Page 87, Table 7, Oxisols, Aquox. Delete: "Gibbsiaquox, Ochraquox, and Umbraquox." Add: "Acraquox, Eutraquox, and Haplaquox."

Page 87, Table 7, Oxisols. Delete: "Humox and Orthox and associated great groups."

Page 87, Table 7, Oxisols. Following Aquox, add: "Perox and Acroperox, Eutroperox, Haploperox, Kandiperox, and Sombriperox" respectively under Suborder and Great Group columns.

Page 87, Table 7, Oxisols, Torrox. Under Great Group column, delete: "Torrox"; and add: "Acritorrox, Eutrotorrox, and Haplotorrox."

Page 87, Table 7, Oxisols. Following Torrox, add: "Udox and Acrudox, Eutrudox, Hapludox, Kandiudox, and Sombriudox" respectively under Suborder and Great Group columns.

Page 87, Table 7, Oxisols, Ustox. Following Haplustox, add: "Kandiustox" and move "Sombriustox" to come after "Kandiustox."

Page 88, Table 9, formative elements. Following Orth, add: "Per----L. *per*, throughout in time----(omit mnemonicon)- --Perudic moisture regime."

Page 90, Table 11. Following Aeric, add: "Anionic-----Gr. *anion*-----Anion-----Positively charged colloid."

Page 90, Table 11. Following Grossarenic, add: "Humic-----L. *humus*, earth------Humus------Presence of organic matter."

Page 90, Table 11. Following Plinthic, add: "Rhodic------Gr. base of *rhodon*, rose-------Rhododendron------- Dark red color."

Page 90, Table 11. Following Thapto, add: "Xanthic------Gr. *xanthos*------(omit mnemonicon)------Yellow.

Page 91, first column, last paragraph beginning with line 39. Delete the first two sentences and substitute the following: "Next, for the Oxisols, each great group is followed by a key to the subgroups, and the proper subgroup is the first one that appears to include the soil in question. For the other orders, there is a definition of the typic subgroup in terms of selected properties that the typic subgroup must have or must not have and definitions of other known subgroups in terms that are relative to the typic subgroup. These definitions are followed, in most cases, by a brief description and discussion of each known subgroup. It is important . . ."

Page 92, first column, item C. Change item C to read:

"C. Other soils that have:

1) an oxic horizon with its upper boundary within 150 cm of the soil surface and do not have a clay content increase necessary to define the upper boundary of a kandic horizon within a depth of 150 cm of the soil surface, or
2) 40 percent or more clay in the surface 18 cm, after mixing, and, with its upper boundary within 150 cm of the soil surface, either an oxic horizon, or a kandic horizon that meets the weatherable mineral requirements of an oxic horizon."

Oxisols, p. 323

Page 92, delete footnote 1.

National Soil Taxonomy Handbook issue No. 1, page 615-10 (Page 93, second column, item I.). Change item I.4. to read:

"4. A fragipan or an oxic horizon with its upper boundary between a depth of 150 and 200 cm."

Page 96, first column, item 6. Change to read:

"Do not have an oxic horizon within 150 cm of the soil surface and do not have a kandic horizon within 150 cm of the soil surface if there is 40 percent or more clay in the surface 18 cm, after mixing, and the kandic horizon meets the weatherable mineral requirements of an oxic horizon."

Page 96, first column, Limits between Alfisols and soils of other orders, item 5. Change to read:

"5. To distinguish Alfisols from Oxisols, Alfisols must not have an oxic horizon within 150 cm of the soil surface or a kandic horizon within 150 cm of the soil surface if there is 40 percent or more clay in the surface 18 cm, after mixing, and the kandic horizon meets the weatherable mineral requirements of an oxic horizon."

Page 100, Plate 4D. Change Tropeptic Haplorthox to "Rhodic Hapludox."

Page 155, second column, Definition. Change item 1 to read:

"1. Do not have an oxic or spodic horizon or a kandic horizon within 150 cm of the soil surface if there is 40 percent or more clay in the surface 18 cm, after mixing, and the kandic horizon meets the weatherable mineral requirements of an oxic horizon."

Page 156, second column. Change item 6 to read:

"6. To distinguish Aridisols from Oxisols, Aridisols must not have an oxic horizon within 150 cm of the soil surface or a kandic horizon within 150 cm of the soil surface if there is 40 percent or more clay in the surface 18 cm, after mixing, and the kandic horizon meets the weatherable mineral requirements of an oxic horizon."

Page 180, top of second column. Change item 6 to read:

"6. To distinguish Entisols from Oxisols, Entisols must not have an oxic or kandic horizon."

Page 227, second column, Definition. Change item 1.a to read:

"a. Do not have a spodic, argillic, kandic, or natric horizon, or an oxic horizon within 150 cm of the soil surface, unless . . ."

National Soil Taxonomy Handbook issue No. 1, page 615-13 (Page 272, first column, item renumbered as 5). Change to read:

"5. Do not have an oxic horizon within 150 cm of the soil surface and do not have a kandic horizon within 150 cm of the soil surface if there is 40 percent or more clay in the surface 18 cm, after mixing, and the kandic horizon meets the weatherable mineral requirements of an oxic horizon."

Page 272, second column. Change item 6 to read:

"6. To distinguish Mollisols from Oxisols, Mollisols must not have an oxic horizon within 150 cm of the soil surface or a kandic horizon within 150 cm of the soil surface if there is 40 percent or more clay in the surface 18 cm, after mixing, and the kandic horizon meets the weatherable mineral requirements of an oxic horizon."

Pages 323 through 332. Delete and replace Chapter 14 with the following:

Chapter 14
Oxisols

Oxisols (plate 4D) are reddish, yellowish, or grayish colored soils. They are most common on the gentle slopes of geologically old surfaces in tropical and subtropical regions. Their profiles are distinctive because of the lack of obvious horizons. Their surface horizons are usually somewhat darker in color than the subsoil, but the transition of subsoil features is gradual.

Oxisols consist mainly of quartz, kaolinite, oxides, and organic matter. Both the structure and "feel" of Oxisols are deceptive. Upon first examination they appear structureless and feel like a loamy particle size. While some are loamy or even coarser, many are extremely clayey, but that clay is aggregated in a strong grade of fine and very fine granular structure. To obtain a true "feel" of the fine texture, a wet sample must be worked for several minutes in the hands to break down the sandy-feeling, granular structure. The strong granular structure apparently causes most Oxisols to have a much more rapid permeability than would be predicted by the particle-size distribution class. Although compaction and reduction in permeability can be caused by cultivation, they are extremely resistant to compaction and so free draining that cultivation can take place soon after rain without puddling.

Oxisols are present in every soil moisture regime from aridic to perudic and aquic. Natural vegetation ranges from tropical rain forests to desert savannas. The lack of a unifying climatic factor throughout their geographic distribution indicates that their formation is genetically controlled by parent material parameters. As part of the definition, they are limited to very low cation-exchange capacities and weatherable mineral contents. They are present over many kinds of geologic bedrock but upon close examination, often to great depth, there is evidence that the material from which the soil forms has been transported. Where the material is not clearly transported, formation is most common in mafic rock.

Although many Oxisols are extremely infertile, there are some that have small but adequate supplies of nutrients and are immediately productive when cultivated. The reserves of plant nutrients even in the most fertile Oxisols are not great and to sustain high yields, fertilizers and lime are needed after only a few years of cultivation. In most of the Oxisols, fertilizers are needed for the first crop unless enough fertility for one or two crops is available from the ash derived from burning the natural vegetation. Phosphorus is generally the most restrictive plant nutrient, mainly because of the tendency for the clay- and oxide-rich surface horizon to fix large amounts of fertilizer phosphorus in an unavailable form. However, once this capacity to fix the phosphate has been overcome by an initial application, there is no further fixation problem and annual fertilizer rates are no higher than for other soils. Because of the initial expense of fertilization, Oxisols are cultivated extensively only where modern agronomic techniques are sustainable by an infrastructure of agrobusiness. In primitive, shifting cultivation they are used only if they naturally support a large biomass to yield a large volume of ash upon burning.

Road building and other engineering practices are relatively easy in most Oxisols because of the physical stability of the clay. There is little silt in most Oxisols, thus they have an extremely low available water holding capacity. Soil organic matter contents are usually much higher than indicated by the soil color. This may be due to red staining of the associated iron oxides. Frequently this organic matter is very stable, infertile humus, and is slow to decompose.

The most extensive areas of Oxisols are on the interior plateaus of South America, the lower portion of the Amazon basin, significant portions of the central African basin, and important areas in Asia, Australia, and several tropical and subtropical islands.

Definition

Oxisols are mineral soils that

"1. Meet one of these two requirements:
   a. Have an oxic horizon with its upper boundary within 150 cm of the soil surface and do not have a clay content increase necessary to define the upper boundary of a kandic horizon within a depth of 150 cm; or
   b. Have 40 percent or more clay in the surface 18 cm, after mixing, and, within 150 cm of the soil surface, either an oxic horizon or a kandic horizon that meets the weatherable mineral requirements of an oxic horizon; and
2. Do not have a spodic horizon.

Key to suborders

CA Oxisols that are either saturated with water within 30 cm of the mineral soil surface 30 days per year in most years or artificially drained, and have one or more of the following:
   1) a histic epipedon;
   2) if faintly mottled or not mottled within 50 cm of the soil surface, an epipedon that has a moist color value less than 3.5 and chroma of 2 or less immediately below the epipedon; or
   3) if there are distinct or prominent mottles within 50 cm of the soil surface, a chroma of 3 or less or a hue of 2.5Y or yellower in 50 percent or more of the horizon immediately below the epipedon.

Aquox

CB Other Oxisols that have an aridic soil moisture regime.

Torrox

CC Other Oxisols that have an ustic soil moisture regime.

Ustox

CD Other Oxisols that have a perudic soil moisture regime.

Perox

CE Other Oxisols.

Udox

Aquox

These are wet Oxisols. They are present in shallow depressions and as seepage areas at the base of slopes. Because the water table may seasonally fluctuate within the profiles, there is a tendency to accumulate iron in the form of secondary nodules, concretions, and plinthite. Most areas are small.

Definition

Aquox are the Oxisols that are saturated with water within 30 cm of the mineral surface 30 days or more per year in most years or are artificially drained and have one or more of the following:

1. A histic epipedon;
2. If not mottled, a moist color value less than 3.5 and a dominant chroma of 2 or less immediately below the epipedon; or
3. If there are distinct or prominent mottles within a depth of 50 cm of the soil surface, a dominant chroma of 3 or less or a hue of 2.5Y or yellower in 50 percent or more of the horizon immediately below the epipedon.

Key to great groups

CAA Aquox that have an apparent ECEC of less than 1.50 meq/100 g clay and a pH value (1*N* KCl) of 5 or more in some part of the oxic horizon within a depth of 150 cm of the soil surface.

Acraquox

CAB Other Aquox that have plinthite forming a continuous phase within a depth of 125 cm of the soil surface.

Plinthaquox

CAC Other Aquox that have more than 35 percent base saturation (NH_4OAc) in all parts within a depth of 125 cm of the soil surface.

Eutraquox

CAD Other Aquox.

Haplaquox

Acraquox

This great group is provided for those Aquox with extremely low cation-exchange capacities. Few examples have been made available for study.

Definition

Acraquox are the Aquox that have an apparent ECEC of less than 1.50 meq/100 g clay and a pH value (1*N* KCl) of 5 or more in some part of the oxic horizon within a depth of 150 cm of the soil surface.

Key to subgroups

CAAA Acraquox that have more than 5 percent plinthite in some horizon within a depth of 125 cm of the soil surface.

Plinthic Acraquox

CAAB Other Acraquox that have mottles with chroma of more than 2 in 50 percent or more of the horizon immediately below the epipedon.

Aeric Acraquox

CAAC Other Acraquox.

Typic Acraquox

Eutraquox

These Aquox have base saturation of more than 35 percent at pH 7 in all horizons to a depth of 125 cm.

Definition

Eutraquox are the Aquox that

1. Have more than 35 percent base saturation (NH_4OAc) in all parts within a depth of 125 cm of the soil surface;
2. Do not have plinthite that forms a continuous phase withina depth of 125 cm of the soil surface; and
3. Do not have an apparent ECEC of less than 1.50 meq/100 g clay and a pH value (1*N* KCl) of 5 or more in some part of the oxic horizon within a depth of 150 cm of the soil surface.

Key to subgroups

CACA Eutraquox that have a histic epipedon.

Histic Eutraquox

CACB Other Eutraquox that have more than 5 percent plinthite in some horizon within a depth of 125 cm of the soil surface.

Plinthic Eutraquox

CACC Other Eutraquox that have mottles with chroma of more than 2 in 50 percent or more of the horizon immediately below the epipedon.

Aeric Eutraquox

CACD Other Eutraquox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter.

Humic Eutraquox

CACE Other Eutraquox.

Typic Eutraquox

Haplaquox

These are low base status Aquox.

Definition

Haplaquox are the Aquox that

1. Have 35 percent or less base saturation (NH_4OAc) in some or all parts within a depth of 125 cm of the soil surface;
2. Do not have plinthite that forms a continuous phase within a depth of 125 cm of the soil surface; and
3. Do not have an apparent ECEC of less than 1.50 meq/100 g clay and a pH value (1*N* KCl) of 5 or more in some part of the oxic horizon within a depth of 150 cm of the soil surface.

Key to subgroups

CADA Haplaquox that have a histic epipedon.

Histic Haplaquox

CADB Other Haplaquox that have more than 5 percent plinthite in some horizon within a depth of 125 cm of the soil surface.

Plinthic Haplaquox

CADC Other Haplaquox that have mottles with a chroma of more than 2 in 50 percent or more of the horizon immediately below the epipedon.

Aeric Haplaquox

CADD Other Haplaquox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of the surface litter.

Humic Haplaquox

CADE Other Haplaquox.

Typic Haplaquox

Plinthaquox

This great group is provided for pedons of Aquox that have continuous plinthite within 125 cm of the soil surface. Only small areas of Plinthaquox have been observed and no data has been made available for study.

Definition

Plinthaquox are the Aquox that

1. Have plinthite that forms a continuous phase within a depth of 125 cm of the soil surface; and
2. Do not have an apparent ECEC of less than 1.50 meq/100 g clay and a pH value (1*N* KCl) of 5 or more in some part of the oxic horizon within a depth of 150 cm of the soil surface.

Key to subgroups

CABA Plinthaquox that have mottles with chroma of more than 2 in 50 percent or more of the horizon immediately below the epipedon.

Aeric Plinthaquox

CABB Other Plinthaquox.

Typic Plinthaquox

Perox

This is a new suborder. Although the perudic soil moisture regime was defined as one in which precipitation equals or exceeds potential evapotranspiration every month of the year, the criterion was not used in Soil Taxonomy (1975). Perox are well-drained Oxisols with a perudic soil moisture regime. Clearing and burning is difficult because of atmospheric wetness. Also, it is difficult to cure many seed crops and storage of produce is difficult. There are not large areas of perudic soil moisture regime, but they

appear distinctive enough to show and identify on some small-scale soil maps. If found useful, perhaps the concept should be considered in other orders.

Definition

Perox are the Oxisols that have a perudic soil moisture regime.

Key to great groups

CDA Perox that have a sombric horizon within 150 cm of the soil surface.

Sombriperox

CDB Other Perox that have both an apparent ECEC of less than1.50 meq/100 g clay and a pH value (1*N* KCl) of 5 or more in some part of the oxic or kandic horizon within a depth of 150 cm of the soil surface.

Acroperox

CDC Other Perox that have more than 35 percent base saturation (NH_4OAc) in all parts within a depth of 125 cm of the soil surface.

Eutroperox

CDD Other Perox that have more than 40 percent clay in the surface 18 cm, after mixing, and the upper boundary of a kandic horizon occurring within a depth of 150 cm of the soil surface.

Kandiperox

CDE Other Perox.

Haploperox

Acroperox

These are well-drained Oxisols in the perudic soil moisture regime that have very low cation exchange values.

Definition

Acroperox are the Perox that

1. Have an apparent ECEC of less than 1.50 meq/100 g clay and a pH value (1*N* KCl) of 5 or more in some part of the oxic or kandic horizon within a depth of 150 cm of the soil surface; and
2. Do not have a sombric horizon within a depth of 150 cm of the soil surface.

Key to subgroups

CDBA Acroperox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface and a petroferric contact within 125 cm of the soil surface.

Aquic Petroferric Acroperox

CDBB Other Acroperox that have a petroferric contact within 125 cm of the soil surface.

Petroferric Acroperox

CDBC Other Acroperox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface and a lithic contact within 125 cm of the soil surface.

Aquic Lithic Acroperox

CDBD Other Acroperox that have a lithic contact within a depth of 125 cm of the soil surface.

Lithic Acroperox

CDBE Other Acroperox that have a delta pH (KCl pH - 1:1 water pH) with a 0 or net positive charge in some layer 18 cm or more thick within a depth of 125 cm of the soil surface.

Anionic Acroperox

CDBF Other Acroperox that have more than 5 percent plinthite in some horizon within a depth of 125 cm of the soil surface.

Plinthic Acroperox

CDBG Other Acroperox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface.

Aquic Acroperox

CDBH Other Acroperox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter and a color hue of 2.5YR or redder with moist values of less than 4 in most of the 25 to 125 cm depth from the soil surface.

Humic Rhodic Acroperox

CDBI Other Acroperox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter and color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25 to 125 cm depth from the soil surface.

Humic Xanthic Acroperox

CDBJ Other Acroperox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter.

Humic Acroperox

CDBK Other Acroperox that have a color hue of 2.5YR or redder with moist values of less than 4 in most of the 25 to 125 cm depth from the soil surface.

Rhodic Acroperox

CDBL Other Acroperox that have a color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25 to 125 cm depth from the soil surface.

Xanthic Acroperox

CDBM Other Acroperox.

Typic Acroperox

Eutroperox

This great group is provided for Oxisols in the perudic soil moisture regime with high base saturation. No examples have been available for testing.

Definition

Eutroperox are the Perox that

1. Have more than 35 percent base saturation (NH_4OAc) in all parts within a depth of 125 cm of the soil surface;
2. Do not have a sombric horizon within a depth of 150 cm of the soil surface; and
3. Do not have an apparent ECEC of less than 1.50 meq/100 g clay and a pH value (1*N* KCl) of 5 or more in some part of the oxic or kandic horizon within a depth of 150 cm of the soil surface.

Key to subgroups

CDCA Eutroperox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface and a petroferric contact within 125 cm of the soil surface.

Aquic Petroferric Eutroperox

CDCB Other Eutroperox that have a petroferric contact within 125 cm of the soil surface.

Petroferric Eutroperox

CDCC Other Eutroperox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface and a lithic contact within 125 cm of the soil surface.

Aquic Lithic Eutroperox

CDCD Other Eutroperox that have a lithic contact within a depth of 125 cm of the soil surface.

Lithic Eutroperox

CDCE Other Eutroperox that have more than 5 percent plinthite in some horizon within a depth of 125 cm of the soil surface and mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface.

Plinthaquic Eutroperox

CDCF Other Eutroperox that have more than 5 percent plinthite in some horizon within a depth of 125 cm of the soil surface.

Plinthic Eutroperox

CDCG Other Eutroperox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface.

Aquic Eutroperox

CDCH Other Eutroperox that have more than 40 percent clay in the surface 18 cm after mixing and the upper boundary of a kandic horizon within a depth or 150 cm of the soil surface.

Kandiudalfic Eutroperox

CDCI Other Eutroperox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter and have the lower boundary of the oxic horizon within a depth of 125 cm of the soil surface.

Umbreptic Eutroperox

CDCJ Other Eutroperox that have the lower boundary of the oxic horizon within a depth of 125 cm of the soil surface.

Inceptic Eutroperox

CDCK Other Eutroperox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter and a color hue of 2.5YR or redder with moist values of less than 4 in most of the 25 to 125 cm depth from the soil surface.

Humic Rhodic Eutroperox

CDCL Other Eutroperox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter and color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25 to 125 cm depth from the soil surface.

Humic Xanthic Eutroperox

CDCM Other Eutroperox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter.

Humic Eutroperox

CDCN Other Eutroperox that have a color hue of 2.5YR or redder with moist values of less than 4 in most of the 25 to 125 cm depth from the soil surface.

Rhodic Eutroperox

CDCO Other Eutroperox that have a color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25 to 125 cm depth from the soil surface.

Xanthic Eutroperox

CDCP Other Eutroperox.

Typic Eutroperox

Haploperox

Only the presence of a perudic soil moisture regime distinguishes these Oxisols from the Udox. Their subsoils have granular structure and the epipedons may be either dark or light colored.

Definition

Haploperox are the Perox that

1. Have 35 percent or less base saturation (NH_4OAc) in some or all parts within a depth of 125 cm of the soil surface;
2. Do not have a sombric horizon within a depth of 150 cm of the soil surface;
3. Do not have an apparent ECEC of less than 1.50 meq/100 g clay and a pH value (1*N* KCl) of 5 or more in some part of the oxic horizon within a depth of 150 cm of the soil surface; and
4. Do not have more than 40 percent clay in the surface 18 cm, after mixing, and an upper boundary of a kandic horizon within a depth of 150 cm of the soil surface.

Key to subgroups

CDEA Haploperox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface and a petroferric contact within 125 cm of the soil surface.

Aquic Petroferric Haploperox

CDEB Other Haploperox that have a petroferric contact within 125 cm of the soil surface.

Petroferric Haploperox

CDEC Other Haploperox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface and a lithic contact within 125 cm of the soil surface.

Aquic Lithic Haploperox

CDED Other Haploperox that have a lithic contact within a depth of 125 cm of the soil surface.

Lithic Haploperox

CDEE Other Haploperox that have more than 5 percent plinthite in some horizon within a depth of 125 cm of the soil surface and mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface.

Plinthaquic Haploperox

CDEF Other Haploperox that have more than 5 percent plinthite in some horizon within a depth of 125 cm of the soil surface.

Plinthic Haploperox

CDEG Other Haploperox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface.

Aquic Haploperox

CDEH Other Haploperox that have an 18 cm or thicker layer inthe upper 75 cm with a bulk density less than 1 g/cc and in which all the Al plus one-half the Fe that is extractable with acid oxalate totals more than 1.0 percent.

Andic Haploperox

CDEI Other Haploperox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter and a color hue of 2.5YR or redder with moist values of less than 4 in most of the 25 to 125 cm depth from the soil surface.

Humic Rhodic Haploperox

CDEJ Other Haploperox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter and color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25 to 125 cm depth from the soil surface.

Humic Xanthic Haploperox

CDEK Other Haploperox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter.

Humic Haploperox

CDEL Other Haploperox that have a color hue of 2.5YR or redder with moist values of less than 4 in most of the 25 to 125 cm depth from the soil surface.

Rhodic Haploperox

CDEM Other Haploperox that have a color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25 to 125 cm depth from the soil surface.

Xanthic Haploperox

CDEN Other Haploperox.

Typic Haploperox

Kandiperox

These Oxisols with a perudic soil moisture regime have clay-textured surface horizons and a kandic subsurface horizon. Prior to this amendment, they would have been Paleudults. Subsoils often have weak to moderate grades of blocky structure. No pedons have been studied.

Definition

Kandiperox are the Perox that

1. Have more than 40 percent clay in the surface 18 cm, after mixing, and an upper boundary of a kandic horizon within a depth of 150 cm of the soil surface;

2. Have 35 percent or less base saturation (NH_4OAc) in some or all parts within a depth of 125 cm of the soil surface;
3. Do not have a sombric horizon within a depth of 150 cm of the soil surface; and
4. Do not have an apparent ECEC of less than 1.50 meq/100 g clay and a pH value (1*N* KCl) of 5 or more in some part of the oxic horizon within a depth of 150 cm of the soil surface.

Key to subgroups

CDDA Kandiperox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface and a petroferric contact within 125 cm of the soil surface.

Aquic Petroferric Kandiperox

CDDB Other Kandiperox that have a petroferric contact within 125 cm of the soil surface.

Petroferric Kandiperox

CDDC Other Kandiperox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface and a lithic contact within 125 cm of the soil surface.

Aquic Lithic Kandiperox

CDDD Other Kandiperox that have a lithic contact within a depth of 125 cm of the soil surface.

Lithic Kandiperox

CDDE Other Kandiperox that have more than 5 percent plinthite in some horizon within a depth of 125 cm of the soil surface and mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface.

Plinthaquic Kandiperox

CDDF Other Kandiperox that have more than 5 percent plinthite in some horizon within a depth of 125 cm of the soil surface.

Plinthic Kandiperox

CDDG Other Kandiperox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface.

Aquic Kandiperox

CDDH Other Kandiperox that have an 18 cm or thicker layer in the upper 75 cm with a bulk density less than 1 g/cc and in which all the Al plus one-half the Fe that is extractable with acid oxalate totals more than 1.0 percent.

Andic Kandiperox

CDDI Other Kandiperox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter and a color hue of 2.5YR or redder with moist values of less than 4 in most of the 25 to 125 cm depth from the soil surface.

Humic Rhodic Kandiperox

CDDJ Other Kandiperox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter and color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25 to 125 cm depth from the soil surface.

Humic Xanthic Kandiperox

CDDK Other Kandiperox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter.

Humic Kandiperox

CDDL Other Kandiperox that have a color hue of 2.5YR or redder with moist values of less than 4 in most of the 25 to 125 cm depth from the soil surface.

Rhodic Kandiperox

CDDM Other Kandiperox that have a color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25 to 125 cm depth from the soil surface.

Xanthic Kandiperox

CDDN Other Kandiperox.

Typic Kandiperox

Sombriperox

These Perox are not known at this time but are expected to be present.

Definition

Sombriperox are the Perox that have a sombric horizon within a depth of 150 cm of the soil surface.

Key to subgroups

CDAA Sombriperox that have a petroferric contact within a depth of 125 cm of the soil surface.
Petroferric Sombriperox

CDAB Other Sombriperox that have a lithic contact within a depth of 125 cm of the soil surface.
Lithic Sombriperox

CDAC Other Sombriperox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter.
Humic Sombriperox

CDAD Other Sombriperox.
Typic Sombriperox

Torrox

These are Oxisols of the arid regions. They frequently have a higher base saturation than other Oxisols and, when irrigated and fertilized, are excellent soils for a variety of crops. Their known occurrence is limited to Hawaii and perhaps some areas in Australia. Pedon 107 illustrates the Torrox in Hawaii.

Definition

Torrox are the Oxisols that have a torric moisture regime.

Key to great groups

CBA Torrox that have both an apparent ECEC of less than 1.50 meq/100 g clay and a pH value (1*N* KCl) of 5 or more in some part of the oxic horizon within a depth of 150 cm of the soil surface.
Acrotorrox

CBB Other Torrox that have more than 35 percent base saturation (NH_4OAc) in all parts within a depth of 125 cm of the soil surface.
Eutrotorrox

CBC Other Torrox.
Haplotorrox

Acrotorrox

This great group is provided for Torrox with very low cation-exchange values. No examples have been available for study.

Definition

Acrotorrox are the Torrox that have an apparent ECEC of less than 1.50 meq/100 g clay and a pH value (1*N* KCl) of 5 or more in some part of the oxic horizon within a depth of 150 cm of the soil surface.

Key to subgroups

CBAA Acrotorrox that have a petroferric contact within a depth of 125 cm of the soil surface.
Petroferric Acrotorrox

CBAB Other Acrotorrox that have a lithic contact within a depth of 125 cm of the soil surface.
Lithic Acrotorrox

CBAC Other Acrotorrox.
Typic Acrotorrox

Eutrotorrox

These high base-saturated Torrox are best known in the Hawaiian Islands where they are used for irrigated crops.

Definition

Eutrotorrox are the Torrox that

1. Have more than 35 percent base saturation (NH_4OAc) in all parts within a depth of 125 cm of the soil surface; and
2. Do not have an apparent ECEC of less than 1.50 meq/100 g clay and a pH value (1*N* KCl) of 5 or more in some part of the oxic horizon within a depth of 150 cm of the soil surface.

Key to subgroups

CBBA Eutrotorrox that have a petroferric contact within a depth of 125 cm of the soil surface.
Petroferric Eutrotorrox

CBBB Other Eutrotorrox that have a lithic contact within a depth of 125 cm of the soil surface.
Lithic Eutrotorrox

CBBC Other Eutrotorrox.
Typic Eutrotorrox

Haplotorrox

This great group is provided for other Torrox that are low in base saturation percentage. No examples have been available for study.

Definition

Haplotorrox are the Torrox that

1. Have 35 percent or less base saturation (NH_4OAc) in some or all parts within a depth of 125 cm of the soil surface; and
2. Do not have an apparent ECEC of less than 1.50 meq/100 g clay and a pH value (1*N* KCl) of 5 or more in some part of the oxic horizon within 150 cm of the soil surface.

Key to subgroups

CBCA Haplotorrox that have a petroferric contact within a depth of 125 cm of the soil surface.
Petroferric Haplotorrox

CBCB Other Haplotorrox that have a lithic contact within a depth of 125 cm of the soil surface.
Lithic Haplotorrox

CBCC Other Haplotorrox.
Typic Haplotorrox

Udox

Previously these Oxisols with udic soil moisture regimes were known as Orthox. The connotation of orth is the "true" Oxisols, and this certainly was the concept of Oxisols as Soil Taxonomy was prepared. It now appears that there is as much extent, or perhaps more, of Ustox than Udox. Many of the soils in the udic soil moisture regime of the upper Amazon basin classify as Ultisols rather than Oxisols as originally thought. Therefore it appears inappropriate to refer to well drained Oxisols with udic soil moisture regimes as "the true" Oxisols, and the name Udox is selected in keeping with usage in other orders. There are less than 90 days during which crops are not planted; however, there are one to three months in most years that are considered "dry" in local terms.

Definition

Udox are the Oxisols that have an udic moisture regime.

Key to great groups

CEA Udox that have a sombric horizon within a depth of 150 cm of the soil surface.
Sombriudox

CEB Other Udox that have both an apparent ECEC of less than 1.50 meq/100 g clay and a pH value (1*N* KCl) of 5 or more in some part of the oxic or kandic horizon within a depth of 150 cm of the soil surface.

Acrudox

CEC Other Udox that have more than 35 percent base saturation (NH_4OAc) in all parts within a depth of 125 cm of the soil surface.

Eutrudox

CED Other Udox that have more than 40 percent clay in the surface 18 cm after mixing, and the upper boundary of a kandic horizon occurring within a depth of 150 cm of the surface.

Kandiudox

CEE Other Udox.

Hapludox

Acrudox

These are Udox with very low CEC values in the subsoil. Frequent but small applications of fertilizer and lime are required. Because the CEC is low, the amount of exchangeable Al in the subsoil is low and can be corrected by leaching basic cations from lime and fertilizer.

Definition

Acrudox are the Udox that

1. Have an apparent ECEC of less than 1.50 meq/100 g clay and a pH value (1*N* KCl) of 5 or more in some part of the oxic or kandic horizon within a depth of 150 cm of the soil surface; and
2. Do not have a sombric horizon within a depth of 150 cm of the soil surface.

Key to subgroups

CEBA Acrudox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface and a petroferric contact within 125 cm of the soil surface.

Aquic Petroferric Acrudox

CEBB Other Acrudox that have a petroferric contact within 125 cm of the soil surface.

Petroferric Acrudox

CEBC Other Acrudox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface and a lithic contact within 125 cm of the soil surface.

Aquic Lithic Acrudox

CEBD Other Acrudox that have a lithic contact within a depth of 125 cm of the soil surface.

Lithic Acrudox

CEBE Other Acrudox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface and have a delta pH (KCl pH - 1:1 water pH) with a 0 or net positive charge in some layer 18 cm or more thick within a depth of 125 cm of the soil surface.

Aquic Anionic Acrudox

CEBF Other Acrudox that have a delta pH (KCl pH - 1:1 water pH) with a 0 or net positive charge in some layer 18 cm or more thick within a depth of 125 cm of the soil surface.

Anionic Acrudox

CEBG Other Acrudox that have more than 5 percent plinthite in some horizon within a depth of 125 cm of the soil surface.

Plinthic Acrudox

CEBH Other Acrudox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface.

Aquic Acrudox

CEBI Other Acrudox that have more than 35 percent base saturation (NH_4OAc) in all parts within a depth of 125 cm of the soil surface.

Eutric Acrudox

CEBJ Other Acrudox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter and a color hue of 2.5YR or redder with moist values of less than 4 in most of the 25 to 125 cm depth from the soil surface.

Humic Rhodic Acrudox

CEBK Other Acrudox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter and color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25 to 125 cm depth from the soil surface.

Humic Xanthic Acrudox

CEBL Other Acrudox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter.

Humic Acrudox

CEBM Other Acrudox that have a color hue of 2.5YR or redder with moist values of less than 4 in most of the 25 to 125 cm depth from the soil surface.

Rhodic Acrudox

CEBN Other Acrudox that have a color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25 to 125 cm depth from the soil surface.

Xanthic Acrudox

CEBO Other Acrudox.

Typic Acrudox

Eutrudox

These are Udox with high base saturation throughout the profile. These are highly valued by shifting cultivators and are most common in areas near basic geologic rock.

Definition

Eutrudox are the Udox that

1. Have more than 35 percent base saturation (NH_4OAc) in all parts within a depth of 125 cm of the soil surface;
2. Do not have a sombric horizon within a depth of 150 cm of the soil surface; and
3. Do not have an apparent ECEC of less than 1.50 meq/100 g clay and a pH value (1*N* KCl) of 5 or more in some part of the oxic or kandic horizon within a depth of 150 cm of the soil surface.

Key to subgroups

CECA Eutrudox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface and a petroferric contact within 125 cm of the soil surface.

Aquic Petroferric Eutrudox

CECB Other Eutrudox that have a petroferric contact within 125 cm of the soil surface.

Petroferric Eutrudox

CECC Other Eutrudox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface and a lithic contact within 125 cm of the soil surface.

Aquic Lithic Eutrudox

CECD Other Eutrudox that have a lithic contact within a depth of 125 cm of the soil surface.

Lithic Eutrudox

CECE Other Eutrudox that have more than 5 percent plinthite in some horizon within a depth of 125 cm of the soil surface and mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface.

Plinthaquic Eutrudox

CECF Other Eutrudox that have more than 5 percent plinthite in some horizon within a depth of 125 cm of the soil surface.

Plinthic Eutrudox

CECG Other Eutrudox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface.

Aquic Eutrudox

CECH Other Eutrudox that have more than 40 percent clay in the surface 18 cm after mixing and the upper boundary of a kandic horizon within a depth or 150 cm of the soil surface.

Kandiudalfic Eutrudox

CECI Other Eutrudox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter and have the lower boundary of the oxic horizon within a depth of 125 cm of the soil surface.

Umbreptic Eutrudox

CECJ Other Eutrudox that have the lower boundary of the oxic horizon within a depth of 125 cm of the soil surface.

Inceptic Eutrudox

CECK Other Eutrudox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter and a color hue of 2.5YR or redder with moist values of less than 4 in most of the 25 to 125 cm depth from the soil surface.

Humic Rhodic Eutrudox

CECL Other Eutrudox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter and color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25 to 125 cm depth from the soil surface.

Humic Xanthic Eutrudox

CECM Other Eutrudox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter.

Humic Eutrudox

CECN Other Eutrudox that have a color hue of 2.5YR or redder with moist values of less than 4 in most of the 25 to 125 cm depth from the soil surface.

Rhodic Eutrudox

CECO Other Eutrudox that have a color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25 to 125 cm depth from the soil surface.

Xanthic Eutrudox

CECP Other Eutrudox.

Typic Eutrudox

Hapludox

These Udox are acid and range in color from dark red to pale yellow. They are common in the uplands of Africa, the central part of Indonesia, and many other areas.

Definition

Hapludox are the Udox that

1. Have 35 percent or less base saturation (NH_4OAc) in some or all parts within a depth of 125 cm of the soil surface;
2. Do not have a sombric horizon within a depth of 150 cm of the soil surface;
3. Do not have an apparent ECEC of less than 1.50 meq/100 g clay and a pH value (1*N* KCl) of 5 or more in some part of the oxic horizon within a depth of 150 cm of the soil surface; and
4. Do not have more than 40 percent clay in the surface 18 cm, after mixing, and an upper boundary of a kandic horizon within a depth of 150 cm of the soil surface.

Key to subgroups

CEEA Hapludox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface and a petroferric contact within 125 cm of the soil surface.

Aquic Petroferric Hapludox

CEEB Other Hapludox that have a petroferric contact within 125 cm of the soil surface.

Petroferric Hapludox

CEEC Other Hapludox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface and a lithic contact within 125 cm of the soil surface.

Aquic Lithic Hapludox

CEED Other Hapludox that have a lithic contact within adepth of 125 cm of the soil surface.

Lithic Hapludox

CEEE Other Hapludox that have more than 5 percent plinthite in some horizon within a depth of 125 cm of the soil surface and mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface.

Plinthaquic Hapludox

CEEF Other Hapludox that have more than 5 percent plinthite in some horizon within a depth of 125 cm of the soil surface.

Plinthic Hapludox

CEEG Other Hapludox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface.

Aquic Hapludox

CEEH Other Hapludox that have the lower boundary of the oxic horizon within a depth or 125 cm of the soil surface.

Inceptic Hapludox

CEEI Other Hapludox that have an 18 cm or thicker layer in the upper 75 cm with a bulk density less than 1 g/cc and in which all the Al plus one-half the Fe that is extractable with acid oxalate totals more than 1.0 percent.

Andic Hapludox

CEEJ Other Hapludox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter and a color hue of 2.5YR or redder with moist values of less than 4 in most of the 25 to 125 cm depth from the soil surface.

Humic Rhodic Hapludox

CEEK Other Hapludox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter and color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25 to 125 cm depth from the soil surface.

Humic Xanthic Hapludox

CEEL Other Hapludox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter.

Humic Hapludox

CEEM Other Hapludox that have a color hue of 2.5YR or redder with moist values of less than 4 in most of the 25 to 125 cm depth from the soil surface.

Rhodic Hapludox

CEEN Other Hapludox that have a color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25 to 125 cm depth from the soil surface.

Xanthic Hapludox

CEEO Other Hapludox.

Typic Hapludox

Kandiudox

These Udox have more than 40 percent clay in the surface and an increase in clay content with depth. They have previously been classified as Palcudults and Tropudalfs. The subsoil frequently has a moderate grade of blocky structure.

Definition

Kandiudox are the Udox that

1. Have more than 40 percent clay in the surface 18 cm, after mixing, and an upper boundary of a kandic horizon within a depth of 150 cm of the soil surface;
2. Have 35 percent or less base saturation (NH_4OAc) in some or all parts within a depth of 125 cm of the soil surface;
3. Do not have a sombric horizon within a depth of 150 cm of the soil surface; and
4. Do not have an apparent ECEC of less than 1.50 meq/100 g clay and a pH value (1*N* KCl) of 5 or more in some part of the oxic horizon within a depth of 150 cm of the soil surface.

Key to subgroups

CEDA Kandiudox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface and a petroferric contact within 125 cm of the soil surface.

Aquic Petroferric Kandiudox

CEDB Other Kandiudox that have a petroferric contact within 125 cm of the soil surface.

Petroferric Kandiudox

CEDC Other Kandiudox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface and a lithic contact within 125 cm of the soil surface.

Aquic Lithic Kandiudox

CEDD Other Kandiudox that have a lithic contact within a depth of 125 cm of the soil surface.

Lithic Kandiudox

CEDE Other Kandiudox that have more than 5 percent plinthite in some horizon within a depth of 125 cm of the soil surface and mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface.

Plinthaquic Kandiudox

CEDF Other Kandiudox that have more than 5 percent plinthite in some horizon within a depth of 125 cm of the soil surface.

Plinthic Kandiudox

CEDG Other Kandiudox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface.

Aquic Kandiudox

CEDH Other Kandiudox that have an 18 cm or thicker layer in the upper 75 cm with a bulk density less than 1 g/cc and in which all the Al plus one-half the Fe that is extractable with acid oxalate totals more than 1.0 percent.

Andic Kandiudox

CEDI Other Kandiudox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter and a color hue of 2.5YR or redder with moist values of less than 4 in most of the 25 to 125 cm depth from the soil surface.

Humic Rhodic Kandiudox

CEDJ Other Kandiudox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter and color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25 to 125 cm depth from the soil surface.

Humic Xanthic Kandiudox

CEDK Other Kandiudox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter.

Humic Kandiudox

CEDL Other Kandiudox that have a color hue of 2.5YR or redder with moist values of less than 4 in most of the 25 to 125 cm depth from the soil surface.

Rhodic Kandiudox

CEDM Other Kandiudox that have a color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25 to 125 cm depth from the soil surface.

Xanthic Kandiudox

CEDN Other Kandiudox.

Typic Kandiudox

Sombriudox

These are poorly understood Udox that have an increase in organic carbon content in the subsoil. The only known pedons are near the Rift Valley in Africa.

Definition

Sombriudox are the Udox that have a sombric horizon within a depth of 150 cm of the soil surface.

Key to subgroups

CEAA Sombriudox that have a petroferric contact within a depth of 125 cm of the soil surface.

Petroferric Sombriudox

CEAB Other Sombriudox that have a lithic contact within a depth of 125 cm of the soil surface.

Lithic Sombriudox

CEAC Other Sombriudox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter.

Humic Sombriudox

CEAD other Sombriudox.

Typic Sombriudox

Ustox

The Ustox are those Oxisols that are moist from natural rainfall in most years for at least 90 days, which is usually long enough for one rainfed crop, but not more than 270 days. Thus, crops are not grown continuously because there is inadequate moisture for at least 90 days in most years. Ustox may be the most extensive suborder occurring over a large portion of the interior of South America and in extensive areas of Africa. A few Ustox are in areas of xeric soil moisture regime, for example, in Australia. The range of natural rainfall within the Ustox provides that two crops can be grown on some Ustox while others are limited to only one crop unless supplemental irrigation is available.

Definition

Ustox are the Oxisols that have an ustic moisture regime.

Key to great groups

CCA Ustox that have a sombric horizon within 150 cm of the soil surface.

Sombriustox

CCB Other Ustox that have both an apparent ECEC of less than 1.50 meq/100 g clay and a pH value (1*N* KCl) of 5 or more in some part of the oxic or kandic horizon within a depth of 150 cm of the soil surface.

Acrustox

CCC Other Ustox that have more than 35 percent base saturation (NH_4OAc) in all parts within a depth of 125 cm of the soil surface.

Eutrustox

CCD Other Ustox that have more than 40 percent clay in the surface 18 cm after mixing, and the upper boundary of a kandic horizon occurring within a depth of 150 cm of the soil surface.

Kandiustox

CCE Other Ustox.

Haplustox

Acrustox

These are Ustox with extremely low cation-exchange values. They can easily have their chemical environment altered by fertilizer and lime applications. Because of their low buffering capacity, it is desirable to use small but frequent applications of fertilizer and lime. Low content of exchangeable Al in the subsoil can be corrected by leaching basic cations from lime and fertilizer.

Definition

Acrustox are the Ustox that

1. Have an apparent ECEC of less than 1.50 meq/100 g clay and a pH value (1*N* KCl) of 5 or more in some part of the oxic or kandic horizon within a depth of 150 cm of the soil surface; and
2. Do not have a sombric horizon within a depth of 150 cm of the soil surface.

Key to subgroups

CCBA Acrustox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface and a petroferric contact within 125 cm of the soil surface.

Aquic Petroferric Acrustox

CCBB Other Acrustox that have a petroferric contact within 125 cm of the soil surface.

Petroferric Acrustox

CCBC Other Acrustox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface and a lithic contact within 125 cm of the soil surface.

Aquic Lithic Acrustox

CCBD Other Acrustox that have a lithic contact within a depth of 125 cm of the soil surface.

Lithic Acrustox

CCBE Other Acrustox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface and have a delta pH (KCl pH - 1:1 water pH) with a 0 or net positive charge in some layer 18 cm or more thick within a depth of 125 cm of the soil surface.

Aquic Anionic Acrustox

CCBF Other Acrustox that have a delta pH (KCl pH - 1:1 water pH) with a 0 or net positive charge in some layer 18 cm or more thick within a depth of 125 cm of the soil surface.

Anionic Acrustox

CCBG Other Acrustox that have more than 5 percent plinthite in some horizon within a depth of 125 cm of the soil surface.

Plinthic Acrustox

CCBH Other Acrustox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface.

Aquic Acrustox

CCBI Other Acrustox that have more than 35 percent base saturation (NH_4OAc) in all parts within a depth of 125 cm of the soil surface.

Eutric Acrustox

CCBJ Other Acrustox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter and a color hue of 2.5YR or redder with moist values of less than 4 in most of the 25 to 125 cm depth from the soil surface.

Humic Rhodic Acrustox

CCBK Other Acrustox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter and color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25 to 125 cm depth from the soil surface.

Humic Xanthic Acrustox

CCBL Other Acrustox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter.

Humic Acrustox

CCBM Other Acrustox that have a color hue of 2.5YR or redder with moist values of less than 4 in most of the 25 to 125 cm depth from the soil surface.

Rhodic Acrustox

CCBN Other Acrustox that have a color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25 to 125 cm depth from the soil surface.

Xanthic Acrustox

CCBO Other Acrustox.

Typic Acrustox

Eutrustox

These high base status Ustox are well known by local farmers because of their relatively high native fertility. Often they supported natural forests, while surrounding areas of like rainfall but low base status supported savannas. It is rare to see forest vegetation today because the forests have been completely cut by native farmers. Why these Ustox have high saturation throughout their profile is not known, but they tend to occur over or near basic rocks such as limestone or basalt.

Definition

Eutrustox are the Ustox that

1. Have more than 35 percent base saturation (NH_4OAc) in all parts within a depth of 125 cm of the soil surface;
2. Do not have a sombric horizon within a depth of 150 cm of the soil surface; and
3. Do not have an apparent ECEC of less than 1.50 meq/100 g clay and a pH value (1*N* KCl) of 5 or more in some part of the oxic or kandic horizon within a depth of 150 cm of the soil surface.

Key to subgroups

CCCA Eutrustox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface and a petroferric contact within 125 cm of the soil surface.

Aquic Petroferric Eutrustox

CCCB Other Eutrustox that have a petroferric contact within 125 cm of the soil surface.

Petroferric Eutrustox

CCCC Other Eutrustox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface and a lithic contact within 125 cm of the soil surface.

Aquic Lithic Eutrustox

CCCD Other Eutrustox that have a lithic contact within a depth of 125 cm of the soil surface.

Lithic Eutrustox

CCCE Other Eutrustox that have more than 5 percent plinthite in some horizon within a depth of 125 cm of the soil surface and mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface.

Plinthaquic Eutrustox

CCCF Other Eutrustox that have more than 5 percent plinthite in some horizon within a depth of 125 cm of the soil surface.

Plinthic Eutrustox

CCCG Other Eutrustox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface.

Aquic Eutrustox

CCCH Other Eutrustox that have more than 40 percent clay in the surface 18 cm after mixing and the upper boundary of a kandic horizon within a depth or 150 cm of the soil surface.

Kandiustalfic Eutrustox

CCCI Other Eutrustox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter and have the lower boundary of the oxic horizon within a depth of 125 cm of the soil surface.

Umbreptic Eutrustox

CCCJ Other Eutrustox that have the lower boundary of the oxic horizon within a depth of 125 cm of the soil surface.

Inceptic Eutrustox

CCCK Other Eutrustox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter and a color hue of 2.5YR or redder with moist values of less than 4 in most of the 25 to 125 cm depth from the soil surface.

Humic Rhodic Eutrustox

CCCL Other Eutrustox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter and color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25 to 125 cm depth from the soil surface.

Humic Xanthic Eutrustox

CCCM Other Eutrustox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter.

Humic Eutrustox

CCCN Other Eutrustox that have a color hue of 2.5YR or redder with moist values of less than 4 in most of the 25 to 125 cm depth from the soil surface.

Rhodic Eutrustox

CCCO Other Eutrustox that have a color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25 to 125 cm depth from the soil surface.

Xanthic Eutrustox

CCCP Other Eutrustox.

Typic Eutrustox

Haplustox

These Ustox are present in dark red to yellow and all intervening colors. They represent vast areas in central South America and Africa.

Definition

Haplustox are the Ustox that

1. Have 35 percent or less base saturation (NH_4OAc) in some or all parts within a depth of 125 cm of the soil surface;
2. Do not have a sombric horizon within a depth of 150 cm of the soil surface;
3. Do not have an apparent ECEC of less than 1.50 meq/100 g clay and a pH value (1*N* KCl) of 5 or more in some part of the oxic horizon within a depth of 150 cm of the soil surface; and
4. Do not have more than 40 percent clay in the surface 18 cm, after mixing, and an upper boundary of a kandic horizon within a depth of 150 cm of the soil surface.

Key to subgroups

CCEA Haplustox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface and a petroferric contact within 125 cm of the soil surface.

Aquic Petroferric Haplustox

CCEB Other Haplustox that have a petroferric contact within 125 cm of the soil surface.

Petroferric Haplustox

CCEC Other Haplustox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface and a lithic contact within 125 cm of the soil surface.

Aquic Lithic Haplustox

CCED Other Haplustox that have a lithic contact within a depth of 125 cm of the soil surface.

Lithic Haplustox

CCEE Other Haplustox that have more than 5 percent plinthite in some horizon within a depth of 125 cm of the soil surface and mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface.

Plinthaquic Haplustox

CCEF Other Haplustox that have more than 5 percent plinthite in some horizon within a depth of 125 cm of the soil surface.

Plinthic Haplustox

CCEG Other Haplustox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface and have the lower boundary of the oxic horizon within a depth of 125 cm of the soil surface.

Aqueptic Haplustox

CCEH Other Haplustox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface.

Aquic Haplustox

CCEI Other Haplustox that have the lower boundary of the oxic horizon within a depth or 125 cm of the soil surface.

Inceptic Haplustox

CCEJ Other Haplustox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter and a color hue of 2.5YR or redder with moist values of less than 4 in most of the 25 to 125 cm depth from the soil surface.

Humic Rhodic Haplustox

CCEK Other Haplustox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter and color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25 to 125 cm depth from the soil surface.

Humic Xanthic Haplustox

CCEL Other Haplustox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter.

Humic Haplustox

CCEM Other Haplustox that have a color hue of 2.5YR or redder with moist values of less than 4 in most of the 25 to 125 cm depth from the soil surface.

Rhodic Haplustox

CCEN Other Haplustox that have a color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25 to 125 cm depth from the soil surface.

Xanthic Haplustox

CCEO Other Haplustox.

Typic Haplustox

Kandiustox

These Ustox have more than 40 percent clay in the surface 18 cm and an increase in clay content sufficient to meet the kandic horizon criteria below that depth. Most of these soils have been previously classified as Ultisols or Alfisols. The subsoil seldom contains evidence of translocated clay, but in some pedons they tend to have a weak to moderate grade of blocky structure in the subsoil, although there is usually a strong secondary structure that is fine granular.

Definition

Kandiustox are the Ustox that

1. Have more than 40 percent clay in the surface 18 cm, after mixing, and an upper boundary of a kandic horizon within a depth of 150 cm of the soil surface;
2. Have 35 percent or less base saturation (NH_4OAc) in some or all parts within a depth of 125 cm of the soil surface;
3. Do not have a sombric horizon within a depth of 150 cm of the soil surface; and
4. Do not have an apparent ECEC of less than 1.50 meq/100 g clay and a pH value (1*N* KCl) of 5 or more in some part of the oxic horizon within a depth of 150 cm of the soil surface.

Key to subgroups

CCDA Kandiustox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface and a petroferric contact within 125 cm of the soil surface.

Aquic Petroferric Kandiustox

CCDB Other Kandiustox that have a petroferric contact within 125 cm of the soil surface.

Petroferric Kandiustox

CCDC Other Kandiustox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface and a lithic contact within 125 cm of the soil surface.

Aquic Lithic Kandiustox

CCDD Other Kandiustox that have a lithic contact within a depth of 125 cm of the soil surface.

Lithic Kandiustox

CCDE Other Kandiustox that have more than 5 percent plinthite in some horizon within a depth of 125 cm of the soil surface and mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface.

Plinthaquic Kandiustox

CCDF Other Kandiustox that have more than 5 percent plinthite in some horizon within a depth of 125 cm of the soil surface.

Plinthic Kandiustox

CCDG Other Kandiustox that have mottles of 4 or more value moist and 2 or less chroma within a depth of 125 cm of the soil surface.

Aquic Kandiustox

CCDH Other Kandiustox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter and a color hue of 2.5YR or redder with moist values of less than 4 in most of the 25 to 125 cm depth from the soil surface.

Humic Rhodic Kandiustox

CCDI Other Kandiustox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter and color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25 to 125 cm depth from the soil surface.

Humic Xanthic Kandiustox

CCDJ Other Kandiustox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter.

Humic Kandiustox

CCDK Other Kandiustox that have a color hue of 2.5YR or redder with moist values of less than 4 in most of the 25 to 125 cm depth from the soil surface.

Rhodic Kandiustox

CCDL Other Kandiustox that have a color hue of 7.5YR or yellower with moist values of 6 or more in most of the 25 to 125 cm depth from the soil surface.

Xanthic Kandiustox

CCDM Other Kandiustox.

Typic Kandiustox

Sombriustox

These are poorly understood Ustox. Often this layer has andic properties and spodic properties. The only known pedons are near the Rift Valley in Africa.

Definition

Sombriustox are the Ustox that have a sombric horizon within a depth of 150 cm of the soil surface.

Key to subgroups

CCAA Sombriustox that have a petroferric contact within a depth of 125 cm of the soil surface.

Petroferric Sombriustox

CCAB Other Sombriustox that have a lithic contact within a depth of 125 cm of the soil surface.

Lithic Sombriustox

CCAC Other Sombriustox that have 16 kg or more organic carbon per square meter to a depth of one meter, exclusive of surface litter.

Humic Sombriustox

CCAD Other Sombriustox.

Typic Sombriustox

Page 349, second column. Change item 3 to read:

"3. Do not have a spodic horizon, do not have an oxic horizon within 150 cm of the soil surface, and do not have a kandic horizon within 150 cm of the soil surface if there is 40 percent or more clay in the surface 18 cm, after mixing, and the kandic horizon meets the weatherable mineral requirements of an oxic horizon."

Page 350, second column. Change item 6 to read:

"6. To distinguish Ultisols from Oxisols, Ultisols must not have an oxic horizon within 150 cm of the soil surface or a kandic horizon within 150 cm of the soil surface if there is 40 percent or more clay in the surface 18 cm, after mixing, and the kandic horizon meets the weatherable mineral requirements of an oxic horizon."

Page 386, first column, Choices of 7 or 11 particle-size classes, second paragraph. Delete the words "and Oxisols."

Page 386, second column, Key to mineralogy classes, first paragraph. Change to read:

"All mineral soils, except Oxisols, are placed in the first mineralogy class of the key in Table 12 that accommodates them, although they may appear also to meet the requirements of other mineralogy classes. The correct mineralogy class for Oxisols is determined by using the key in Table 12a. These are keys, not complete definitions . . . which, by definition, are siliceous."

Page 387, Table 12. Change title of this table to read:

"Table 12.--Key to mineralogy classes of mineral soils, except Oxisols"

Page 388. Add the following Table 12a:

"Table 12a.--Key to mineralogy classes of Oxisols

Does the mineralogy control section have:

1. More than 40 percent iron oxide (>28 percent Fe) by citrate-dithionite in the <2 mm fractions?
2. More than 40 percent gibbsite in the <2 mm fractions?
3. 18-40 percent iron oxide (12.6- 28 percent Fe) by citrate-dithionite in the <2 mm fractions?
4. 18-40 percent gibbsite in the <2 mm fractions?
5. More than 50 percent by weight kaolinite in the <0.002 mm fraction?
6. More than 50 percent by weight halloysite in the <0.002 mm fraction?

none of the above---Mixed
1 with or without 2, 4, 5, 6---Ferritic
2 with or without 3, 5, 6---Gibbsitic
3 with or without 5, 6---Ferruginous
4 with or without 5, 6---Allitic
3 and 4 with or without 5, 6---Sesquic
5---Kaolinitic
6---Halloysitic"

Page 388, first column, Calcareous and reaction classes. Starting with fifth paragraph, second sentence, change to read:

"Three classes (acid, nonacid, and allic) are used in selected taxa. The definitions follow:

Acid.--The pH . . .

Nonacid.--The pH . . .

Allic.--There is more than 2 meq of KCl-extractable Al per 100 g soil (<2 mm fraction) in some 30 cm layer in the control section.

Acid and nonacid classes are used only in names of families of Entisols and Aquepts; they are not used in sandy . . . that have carbonatic or gypsic mineralogy. The allic class is used only in names of families of Oxisols."

Page 388, second column, Depth of soil, Shallow. Change to read:

"Less than 50 cm to the upper boundary of a duripan or petrocalcic horizon or to a lithic, paralithic or petroferric contact. Used in lithic and petroferric subgroups of Oxisols and all great groups of Alfisols, Aridisols, Entisols, Inceptisols, Mollisols, Spodosols, and Ultisols, except pergelic subgroups of the cryic great groups and lithic subgroups. It is emphasized that the adjective "shallow" is not used in the family name of lithic subgroups of orders, other than Oxisols, because it would be redundant."

Page 389, Slope or shape of soil—second column, sentence starting in third line. Change to read:

"In aquic great groups, particularly in Aquolls, Aquox, and Aquults, use the shape of the soil as a family differentia. For Aquolls and Aquults use classes of level and sloping as these classes are defined in the Soil Survey Manual. For Aquox use sloping in the names of families if slope is >8 percent. It may be necessary . . ."

Page 687, Classification. Change classification to: "Anionic Acrudox, fine, ferruginous, isohyperthermic."

Page 689, Classification. Change classification to: "Xanthic Hapludox, very-fine, kaolinitic, isohyperthermic."

Page 691, Classification. Change classification to: "Inceptic Eutrudox, very-fine, kaolinitic, isohyperthermic."

Page 693, Classification. Change classification to: "Anionic Acrudox, very-fine, ferritic, isohyperthermic."

Page 695, Classification. Change classification to: "Humic Hapludox, very-fine, ferruginous, isohyperthermic."

Page 697, Classification. Change classification to: "Typic Haplotorrox, very-fine, kaolinitic, isohyperthermic."

References to Additional ICOMAX Activities

Malaysia Thailand Workshop (August 28 - September 9, 1978)

The proceedings of this workshop were published in two volumes: Second International Soil Classification Workshop: Part I Malaysia, edited by F. H. Beinroth and S. Paramanthan, and Part II Thailand, edited by F. H. Beinroth and S. Panichapong. Both volumes were published by the Soil Survey Division, Land Development Dept., Bangkok, Thailand, in 1979. These proceedings contained 13 papers referring directly to Oxisols and several others relating to other soils with low-activity clays. Descriptions and characterization from 7 pedons considered Oxisols at that time and 19 other pedons are presented.

Rwanda Workshop (June 2 - 12, 1981)

The proceedings of this workshop were published in two volumes: Proceedings of the Fourth International Soil Classification Workshop: Part 1, Papers and Part II, Field Trip and Background Soil Data. Both volumes were edited by F.H. Beinroth, H. Neel, and H. Eswaran and published by ABOS-AGCD Agricultural Editions-4. Brussels, Belgium, in 1983. Of the 16 pedons described and characterized, 3 were considered Oxisols at that time.

Brazil Workshop (May 12 - 23, 1986)

The proceedings of this workshop are being prepared at this time.

A volume entitled Calculated Soil Moisture and Temperature Regimes of Profiles of the VIII International Soil Classification Workshop was edited by A. Van Wambeke and published as a contribuiton of the College of Agriculture and Life Sciences, Cornell University, Ithaca, New York, for the Brazil workshop in 1986.

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